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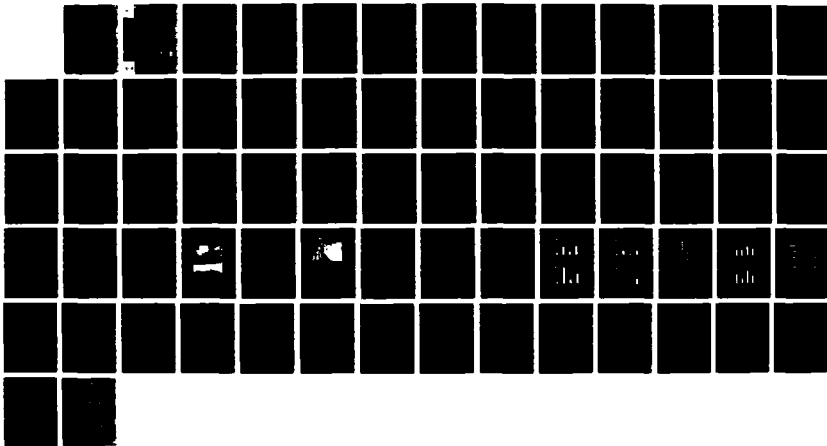
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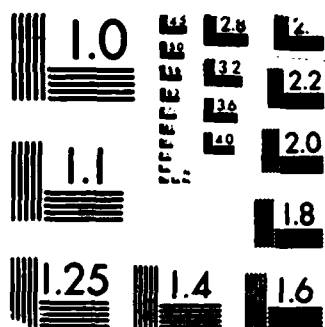
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# BIOLOGICAL AND PHYSICAL CONDITIONS AT A NEWLY PLACED GRAVEL BAR HABITAT IN THE TOMBIGBEE RIVER

by

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Riffles I and II, respectively. The fauna was dominated by oligochaetes and chironomid larvae; both groups made up about 63 percent of the community. By October 1985, approximately 8 months after placement, more than 40 macroinvertebrate taxa had been identified at the site. Total density of macroinvertebrates was estimated at 11,094 and 9,646 individuals/m<sup>2</sup> at Riffles I and II, respectively. Total biomass was 0.6610 and 0.5846 mg/m<sup>2</sup> ash free dry weight (AFDW), respectively. In October 1986, the last collection date for invertebrates, approximately 69 taxa of invertebrates were identified. Densities at Riffles I and II were estimated at 17,949 and 10,983 individuals/m<sup>2</sup>, respectively. Total biomass of invertebrates was estimated at 15.5110 and 4.3290 mg AFDW/m<sup>2</sup> at Riffles I and II, respectively. Approximately 80 taxa of invertebrates have been identified at the gravel bar habitat during the 2-year study.

A total of 42 species were collected in the study area, 39 were found at the gravel bar, 25 were found in the river channel, and 16 were obtained in the flume. Unusual or rare species of fishes were periodically collected at the habitat. The crystal darter, listed as endangered by the State of Mississippi, was found at the habitat, and the blue sucker, considered to be uncommon in the Tombigbee River, was found in the flume. Fish abundance was usually higher at the gravel bar than at the channel or flume. Maximum fish abundance at both the gravel bar and flume was 11.6 catch per minute (CPM) in May 1986 and 8.5 CPM at the river channel in December 1985. Shad dominated the catch at the gravel bar (43.2 percent) as well as all other sites. At the gravel bar, minnows and darters were the second most abundant group (23.8 percent), followed by sunfishes (19.8 percent) and crappie (5.5 percent). Significantly smaller sized fishes were found at the gravel bar (mean length = 94 mm) than at the flume that directs water from Columbus Lake to the river channel (mean length = 188 mm) or river channel below the habitat (mean length = 179 mm). The gravel bar is an important habitat for minnows and juvenile centrarchids while larger individuals are found in the flume and river channel. Estimated fish densities at the Columbus gravel bar (1,100 to 2,900 fishes/ha) were not as high as recorded values from natural riffles (>3,000 fishes/ha). However, lack of large instream cover (e.g. snags, undercut banks, large cobble) probably limits the population. The fish assemblage at the Columbus gravel bar is similar to that in the bendways of the Tombigbee River before completion of the waterway. However, more sport fishes were found at the Columbus site than at other bendways with similar physical conditions.

## PREFACE

In March 1985, the US Army Engineer District, Mobile (SAM), Mobile, Ala., completed construction of a gravel bar habitat in an abandoned channel of the Tombigbee River near Columbus, Miss. The purpose of building this habitat, which was designed by personnel at the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., was to provide a source of cover and food for aquatic organisms that require shallow, flowing water and gravel substrate. When the habitat was complete, scientists at WES, using funds from the Mobile District, initiated a 2-year study of the habitat. This report summarizes the major findings of the study.

This report was prepared by Dr. Andrew C. Miller and Mr. K. Jack Killgore, Aquatic Habitat Group (AHG) WES; Dr. Robert H. King, Central Michigan University, Mt. Pleasant, Mich.; and Ms. Teresa J. Naimo, Tennessee Technological University, Cookeville, Tenn. Assistance in field and laboratory work was provided by Messrs. C. Rex Bingham, Ken Conley, and Johnny Franklin, WES; Dr. Neil Douglas, Northeastern Louisiana University; and Dr. Carl Way, Northwestern University, Ill. Mr. Jack Mallory and Dr. Neil Robison, SAM, assisted in the field and participated in many discussions concerning aquatic habitat development. The report was edited by Ms. Lee T. Byrne of the WES Information Products Division, Information Technology Laboratory.

During the conduct of this study, Dr. Thomas D. Wright was Chief, AHG; Mr. Edwin A. Theriot is the present Chief, AHG. The study was under the general supervision of Dr. Conrad J. Kirby, Chief, Environmental Resources Division, and Dr. John Harrison, Chief, Environmental Laboratory, WES.

Commander and Director of WES is COL Dwayne G. Lee, CE. Technical Director is Dr. Robert W. Whalin.

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# CONTENTS

	<u>Page</u>
PREFACE.....	1
CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT.....	3
PART I: INTRODUCTION.....	4
Background.....	4
Purpose and Scope.....	5
PART II: STUDY AREA AND METHODS.....	6
Study Area.....	6
Methods.....	7
PART III: RESULTS AND DISCUSSION.....	9
Physicochemical Conditions.....	9
Macroinvertebrates.....	10
Fishes.....	17
PART IV: SUMMARY.....	21
General.....	21
Physicochemical Conditions.....	21
Macroinvertebrates.....	22
Fishes.....	23
PART V: RECOMMENDATIONS.....	25
REFERENCES.....	26
TABLES 1-9	
FIGURES 1-16	
APPENDIX A: MICROINVERTEBRATE AND FISHERY DATA FROM THE COLUMBUS GRAVEL BAR AND SELECTED COMPARATIVE SITES.....	A1

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CONVERSION FACTORS, NON-SI TO SI (METRIC)  
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI  
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<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic feet per second	0.02832	cubic metres per second
feet	0.3048	metres
footcandle	10.76	lux
miles (US statute)	1.609347	kilometres

BIOLOGICAL AND PHYSICAL CONDITIONS AT A NEWLY PLACED GRAVEL BAR  
HABITAT IN THE TOMBIGBEE RIVER

PART I: INTRODUCTION

Background

1. Ecosystems altered by construction of dams and channel diversions are now the most prevalent lotic habitats on Earth (Standford and Ward 1979). Throughout the Nation, increased demands placed on lotic ecosystems have intensified the need for habitat improvement and creation. The development of the Tennessee-Tombigbee Waterway (TTW) required considerable modification of the original river, which negatively affected riverine organisms (McClure 1985). The TTW, authorized by Public Law 525 in accordance with recommendations contained in House Document 486 of the 79th Congress, was designed to provide a more direct shipping route between the eastern gulf coast and the mid-continental United States. This was accomplished by connecting the upper portion of the Tombigbee River to the Tennessee River in extreme northeastern Mississippi (Figure 1). The TTW converted the free-flowing Tombigbee River into a series of run-of-the-river reservoirs. Alteration of the fluctuation in water velocities and levels provided habitat for slack-water aquatic species at the expense of organisms that normally inhabit riffles and gravel substrate. The Tombigbee River was well-known for supporting a dense and diverse fauna including sculpins, darters, minnows, snails, worms, and immature insects. The mid portions of the river also provided habitat for many species of freshwater mussels, many of which were collected for commercial purposes.

2. At the request of the US Army Engineer District (USAED), Mobile, a meeting was held on 13 November 1980 at the US Army Engineer Waterways Experiment Station (WES). The purpose of the meeting was to discuss the feasibility of constructing a gravel bar habitat. The habitat would be placed in an abandoned channel of the Tombigbee River (river mile 232.9) directly below a minimum-flow release structure in Columbus Dam near Columbus, Miss. The site was chosen because it was outside the navigation route of the TTW and it would receive constant flow of water (approximately  $5 \text{ m}^3/\text{sec}$ ) from the minimum-flow release structure. In addition, the channel was protected from high-water

velocities that accompany high discharge in the river. The habitat was constructed to provide a source of food and cover for riffle-inhabiting species of fish, aquatic insects, and freshwater mussels.

3. In 1981 scientists at WES prepared a design for the gravel bar habitat. The design was based upon conditions at a natural bar on the Buttahatchie River, a fourth order system near Columbus (Figure 2). A description of the site on the Buttahatchie River, in addition to the design for the habitat, can be found in Miller, King, and Glover (1983).

4. In March 1985, the USAED, Mobile, completed construction of the gravel bars at Columbus. Two separate bars and a pool were constructed using 24,000 m<sup>3</sup> of gravel. Following completion of the habitat, scientists at WES initiated a 2-year study on physical and biological conditions of the site.

#### Purpose and Scope

5. The purpose of this report is to describe physical and biological conditions at the newly completed gravel bar habitat located in the Tombigbee River near Columbus, Miss. The habitat was finished in March 1985; this study was initiated in June 1985 and terminated on 1 January 1987.

## PART II: STUDY AREA AND METHODS

### Study Area

#### The Tombigbee River

6. The Tombigbee River originates in northeastern Mississippi, flows along the eastern section of the state, and enters Alabama south of Columbus, Miss. (Figure 1). It is joined by the Black Warrior River at Demopolis, Ala., and then by the Alabama River. The confluence of the Alabama and Tombigbee Rivers forms the Mobile River, which enters Mobile Bay, an inlet of the Gulf of Mexico. Average discharge at Columbus (from 1899 to 1912 and from 1928 to 1981) was  $183 \text{ m}^3/\text{sec}$ ; minimum and maximum values were 3.6 and  $5,460 \text{ m}^3/\text{sec}$ , respectively (US Geological Survey 1986). The wettest months are December through April, and precipitation for a typical year is about 140 cm.

#### The gravel bar site

7. The gravel bars are located in an abandoned channel of the Tombigbee River immediately below the west end of Columbus Dam (Figure 2). A minimum flow release structure located in Columbus Lake sends approximately  $5 \text{ m}^3/\text{sec}$  of surface water under the dam, where it enters the abandoned channel via a riprapped flume (Figure 3). The release structure was placed in the dam to provide flowing water for the river channel. However, because the channel is about 60 m wide, water from the minimum flow release structure caused no appreciable flow velocities. A design was prepared for gravel riffles to be placed in the upper section of the channel (Miller, King, and Glover 1983). The gravel was to have two functions: (a) provide substrate for aquatic organisms and (b) constrict the channel, thereby causing the water to move at a moderate velocity.

8. The first step in the construction process was to fill an 80-m reach of the channel with random fill material. The material, which consisted of sand, silt, and gravel, was transported to the site by barge and placed with a clamshell dredge. The fill was placed into the channel to an elevation of 130 ft\* msl, which was about 0.5 m below normal water level. This material

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\* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

was then capped with 24,000 m<sup>3</sup> of 2- to 80-mm coarse sand and gravel obtained from a borrow pit and brought in by barge (Figure 4).

9. The gravel was placed to create two shallow riffles in the center of the exposed bar; these are separated by a short pool (Figure 5). Each riffle is 46 m long and 24 m wide and has a maximum depth of 1.2 m. The gravel constricts the channel and creates a velocity of approximately 50 cm/sec, which is sufficient to prevent excess sedimentation but not erode the base material. At high waterway discharges the entire habitat, including the exposed gravel, is covered with backwater from the Tombigbee River. Water velocity then approaches zero since the channel no longer constricts the flow. After levels decline, the water is again restricted to the channels or riffles, and the velocity of 50 cm/sec is sufficient to wash away recently deposited silts and clays.

### Methods

#### Physicochemical

10. Physicochemical data on water and sediments were collected from June 1985 through October 1986. Specific conductance, total and calcium hardness, total alkalinity, turbidity, and pH were measured in the field using Hach Chemical Kits. Dissolved oxygen was determined using the azide modification of the Winkler method (American Public Health Association (APHA) 1975). Water samples for suspended particulates, total phosphorus, orthophosphate phosphorus, total kjeldahl nitrogen, nitrate nitrogen, total organic carbon, and particulate organic carbon were collected and returned to the laboratory and analyzed using standard methods (APHA 1975).

11. Sediments were collected for particle-size distribution and total organic content. Samples were separated into fractions using the following screens: 15.9, 4, 2, 1, 0.5, 0.25, 0.125, and 0.063 mm. Total organic content was determined as loss on ignition after heating to 550<sup>o</sup> C for 24 hr in a muffle furnace. Water depth, water velocity, and light were measured at 1.2-m intervals along a transect across both riffles.

#### Macroinvertebrates

12. Samples for macroinvertebrates were taken twice a year, in June and October, during the same period that physicochemical data were collected. A stratified random design was employed to select 15 benthic samples from each riffle on 20 June and on 16 October 1985. In addition, five samples were

obtained from the pool. In June and October 1985, 35 samples (15 from each riffle and 5 from the pool) were obtained. Five samples for invertebrates were collected from each of the riffles and the pool in June and October 1986. All quantitative samples were obtained with a Petite Ponar (232 cm<sup>2</sup>) grab sampler, which was operated by forcing the jaws closed by hand to ensure a complete sample. In addition to the quantitative samples, qualitative collections were obtained at each riffle. Substrates were washed in a bucket with a No. 30 mesh sieve (0.5-mm openings). The remaining sediments and associated macroinvertebrates were preserved with 15-percent formalin. In the laboratory macroinvertebrates were removed from sediments with the aid of a stereomicroscope (6×) and preserved in 70-percent ethanol for later identification, enumeration, and biomass determination. Oligochaetes were taken directly from 70- to 80-percent ethanol, mounted on slides in a few drops of a medium consisting of CMCP-9/9AF (2/3 CMCP-9 to 1/8 Acid-Fuchsin), allowed to clear for at least 24 hr, and then identified using keys by Hiltunen and Klemm (1980), supplemented by Brinkhurst (1986).

13. Biomass estimates, as ash-free dry weight (AFDW), were made for each taxon by oven drying at 80<sup>o</sup> C until a constant weight was achieved (maximum of 24 hr) and ashing in a muffle furnace at 550<sup>o</sup> C for 4 hr. All weight estimates were made using a Model 29 Cahn electrobalance. Correction factors were used to estimate weight loss due to preservatives.

#### Fishes

14. Fishes were collected in May, August, October, and December at each site between 1300 and 1600 hr using a boat-mounted electroshocker. A 5,000-W generator with a VVP-15 Coffelt electrofisher provided constant direct current at 4 to 6 A and 300 to 400 V. Stunned fishes were collected with long-handled dip nets, weighed to the nearest gram, and measured (total length) to the nearest millimetre. Each collection consisted of a single pass through the site, usually moving upstream. Catch per minute (CPM) of shocking was calculated by dividing the number of fishes by the collecting time in minutes. In addition, total fish density (number per unit area) was determined at the gravel bar in December 1985 and May 1986. At these times the downstream and upstream boundaries of the site were blocked with 6.4-mm mesh nets. Three consecutive passes were made through the habitat with the electroshocking boat. Density was calculated using the Zippin Depletion Method (Platts, Megahan, and Minshall 1983).

## PART III: RESULTS AND DISCUSSION

### Physicochemical Conditions

#### Chemical conditions

15. With the exception of the occasional influence of backwater from the TTW, chemical conditions at the gravel bar are influenced mainly by Columbus Lake. The water at the site can be characterized as moderately hard and alkaline, with low turbidity and reduced nutrients (Table 1). Saturation values for dissolved oxygen ranged from 92 to 100 percent. Water temperature, which was affected by lack of canopy cover and solar radiation (on the impounded waters immediately upriver) ranged from 4° C to 32° C. Total hardness averaged 98.7 mg/l as calcium carbonate; 65 percent originated from calcium, and 35 percent from magnesium hardness. In January, turbidity was low (7 Nephelometric Turbidity Units (NTU)); however, in the spring and summer values of more than 100 NTU were measured.

16. Water quality parameters in the Buttahatchie River, a natural fourth order river close to the study site, were compared with those at the Columbus site. Total hardness, total alkalinity, pH, water temperature, and turbidity were typically lower in the Buttahatchie River than at the gravel bar. Water temperature was lower at the former site because of canopy coverage, which limited heating by solar radiation. Hardness, alkalinity, and turbidity were lower at the Buttahatchie River than at the Columbus site. The Buttahatchie River is a shorter system, and there is less opportunity for contact with inorganic and organic substrates. In general, water quality at the gravel bar site is good and is suitable for the majority of aquatic species adapted to southern climates.

#### Discharge and water depth

17. Water depth and velocity at the substrate water interface differed slightly between the two riffles and through time (Figure 6). Water velocities were slightly higher in the first riffle (closest to the outlet structure) than in the second riffle. At Riffle 1, the percentage of incident light remaining at the bottom ranged from more than 10 to less than 5 percent, depending on season and water clarity (Figure 7). Both riffles were similar with respect to light penetration. The amount of light reaching the bottom of these riffles (5 to 10 percent of surface radiation, usually less than

1,500 fc) is not sufficient to support extensive growth of photosynthetic species (King 1985). For this reason, it is unlikely that algae or submersed aquatic plants will be a dominant feature of these riffles.

#### Sediment

18. Inorganic particles at the habitat consisted of coarse and fine gravel (2 to 80 mm), although sands and silts were also present (Figure 8). By the fall of 1986, nearly 2 years after the habitat had been placed, the substrate in the riffles had not armored. The bottom substrates were unconsolidated, and seasonal differences in bottom profiles were noted (Figure 6). Sediments at the natural gravel bar on the Buttahatchie River exhibited a greater percentage of coarse particulates than did the habitat at Columbus (Figure 8). Although substrate in much of the original Tombigbee River consisted of sand and gravel substrate, the reach near Columbus was described as "predominantly hardpan with mixed mud and sand adjacent to the bank" (Crossman et al. 1975).

19. The sediment at both riffles consisted of approximately 1 percent organic matter (Table 2). There were no significant differences in organic content of sediments among the riffles and pool or between June and October 1985. Detritus and other fine particulate organic matter should gradually accumulate in the substrates at the Columbus gravel bar. Sedimentation will occur most rapidly during periods of high discharge in the TTW. During these periods, current will be reduced because water is not restricted to the riffles. It is anticipated that most of the fine particulates that settle on the substrate will be removed after water levels decline and velocity in the riffles increase. However, some fine organic and inorganic particles should be incorporated into the substrate matrix. During this study period, there were no periods of high water that lasted more than a few days. Fine particulates will probably not increase to any extent until there is an extended period of high water.

#### Macroinvertebrates

##### Macroinvertebrate colonization

20. In June 1985, approximately 80 days after construction, 19 and 21 macroinvertebrate taxa were collected at Riffles I and II, respectively (Tables 3, A1, A2). In October, approximately 200 days after completion, 34

taxa were found at each riffle, and a total of 44 taxa were collected in both riffles. A total of 24 to 25 and 38 to 39 taxa were collected in June and October 1986, respectively. Taxa that were most common in both years were oligochaetes and chironomids (Tables A1, A2). The number of taxa in the pool increased during the 2 years following construction, although species richness was not as high as it was in the riffles. Approximately 80 taxa of invertebrates have been identified at the gravel bar habitat during the 2-year study.

21. After 3 months, total macroinvertebrate densities were 3,496 and 2,868 individuals/m<sup>2</sup> at Riffles I and II, respectively (Table 4). The fauna was dominated by oligochaetes and chironomid larvae; both groups comprised about 63 percent of the community. By October 1985, approximately 8 months after placement, total densities of macroinvertebrates were estimated at 11,094 and 9,646 individuals/m<sup>2</sup> at Riffles I and II, respectively. Total biomasses were 0.6610 and 0.5846 mg/m<sup>2</sup> AFDW, respectively (Table 5). In October 1986, the last collection date for invertebrates, densities at Riffle I and II were estimated at 17,949 and 10,983 individuals/m<sup>2</sup>, respectively. Total biomasses of invertebrates were estimated at 15.5110 and 4.3290 mg AFDW/m<sup>2</sup> at Riffles I and II, respectively.

22. Total numbers and biomass of chironomidae dominated the community in June of the first year (96 and 80 percent, respectively, see Table 6). However, relative to other major invertebrate groups, percentage composition of the chironomidae declined during the study period because of the gradual increase in numbers and biomass of other groups that colonized the site. The substantial increase in biomass of *Corbicula* (90 percent by October 1986, see Table 6), dramatically affected overall community composition. Adult *Corbicula* that are 3 to 4 cm long can weigh several grams; this group often dominates a community in numbers and biomass. Since *Corbicula* can live 2 to 3 years, it has taken longer for these bivalves to colonize the habitat than shorter lived invertebrates. Total number and biomass of naidids and tubificids increased gradually after the first sampling date. Because these groups could not disperse to new areas by flying, they could not reach the habitat as rapidly as the chironomids.

23. Density of a bryozoan, *Umatella gracilis*, was fairly low in samples obtained in June. However, by October 1985 it was a dominant component of the community. *U. gracilis* is a sessile colonial organism composed of one to several stalks, consisting of urn-shaped segments that originate from a

single basal disk (Twitchell 1934). Density estimates for this species are determined by counting stalks. At the Columbus site, 3 to 4 stalks usually comprised a single individual. In October the total number of stalks ranged from 108,400 to 225,065/m<sup>2</sup> (average = 144,614 stalks/m<sup>2</sup>, SD = 47,426). Total biomass was estimated at 868 mg/m<sup>2</sup> AFDW. This species has been reported as an epizooant on clams (Harrel and Wallis 1967; Eng 1977; Hull, Bartos, and Martz 1980; Curry, Everitt, and Vidrine 1981) and the aquatic insect *Corydalis* sp. (Tracy and Hazelwood 1983). It adheres to fishing weights, plastic bottles, etc. (Eng 1977; Hull, Bartos, and Martz 1980; Oda 1982), and plant fragments (Hull, Bartos, and Martz 1980; Wilde, Bruke, and Keenan 1981).

24. Most aquatic insects (for example the Chironomidae) colonize new substrate by downstream drift and dispersal by adults that fly (Fisher 1983, Light and Adler 1983). At the Columbus site, these two mechanisms probably accounted for the majority of the aquatic insects in the riffles and pool. However, upstream movement in the water and along the bottom does occur (Bishop and Hynes 1969), especially by taxa that are solely aquatic throughout their life cycle (Light and Adler 1983). Oligochaetes and planarians can also reach the site by this mechanism, although it is probably not as significant as downstream movement. The Asiatic clam *Corbicula*, can disperse by entering the drift and by being carried on currents by a mucus thread (Prezant and Chalermwat 1984). Juvenile *Corbicula* from the lake or riprapped flume could reach the gravel bar habitat in this manner.

#### Seasonal differences

25. Total macroinvertebrate density was 3 to 4 times higher in the October samples during both study years (Table 4, Figure 9). A similar pattern of seasonality was reported by Mettee, Harris, and O'Neil (1986) based upon a series of monthly samples from streams in Alabama. These seasonal differences in density were probably caused mainly by life history strategies of macroinvertebrates. Invertebrates began to emerge in late winter and spring, and numbers were reduced in the June samples. By early fall, the new recruits were large enough to be collected and became substantial components of the community.

26. Densities of *Corbicula*, *Glyptotendipes* sp., and the Naididae (as well as total macroinvertebrates) were significantly higher (0.05 level or higher) in fall than in June for both years (Table A3, A4). However, there were fewer significant differences for the major taxonomic groups when

compared between years for the same season (Tables A5, A6). For example *Glyptotendipes* sp. and total macroinvertebrates exhibited few or no significant changes between years during either season. *Glyptotendipes* colonized rapidly during the first year and exhibited virtually identical densities both years. *Corbicula* and the Naididae displayed significant changes through time and did not exhibit the seasonal fluctuations of the other taxa. The density values estimated during the present study are within the range of values for riffles in natural systems with the exception of the relatively low values recorded on a gravel bar in the Buttahatchie River (Table 7).

27. Biomass estimates for macroinvertebrates were similar to changes in density (Table 7, Figures 10 and 11). However, as described above, *Corbicula* exhibited significantly greater biomass on each sampling date (Figure 12). Because this species is substantially larger than the other taxa, it can dominate the invertebrate biomass. While biomass estimates increased about three times in the first 200 days, these are much lower than values reported for other lotic systems. The lowest biomass estimate in Table 7 (1.395 g AFDW/m<sup>2</sup> for the Pine River, Mich.) is over twice as high as values for total invertebrates during 1985 at the Columbus site (Table 7). Macroinvertebrate biomass is expected to increase at this study site to a level within the range of values in Table 5. High macroinvertebrate biomass below lakes are attributed to factors such as improved plankton food supplies, enhanced periphyton, and stabilized discharges (Pett 1985). High biomass values are particularly characteristic of sites influenced by epilimnial release (such as the Columbus site).

#### Depth distribution of *Corbicula*

28. Based upon a set of samples taken in late October 1986, the mean density of *Corbicula* was 846 individuals/m<sup>2</sup> (standard error = 274) and 2,462 individuals/m<sup>2</sup> (standard error = 660) in the 0- to 13-cm and 13- to 26-cm depth samples, respectively. These density differences were highly significant ( $t = 4.91$ ,  $df = 12$ ,  $p < 0.001$ ). In addition, there was also a difference in the size distribution of *Corbicula* between the two depth zones (Figure 13). The mean size of *Corbicula* was 12.46 mm (standard error = 0.26) and 9.65 mm (standard error = 0.32) in the 0- to 13-cm and 13- to 26-cm depth samples, respectively. The upper depth fraction was composed primarily of gravel while the lower fraction was a gravel-sand mixture. Juvenile *Corbicula* settled into the deeper strata of the sediments. *Corbicula* are highly mobile;

presumably the juveniles migrated to lower depths where particles were smaller and more stable.

#### Trophic relationships

29. Invertebrates in the collector functional feeding groups dominated the community in terms of number of taxa, density, and biomass at the site (Table 8). The absence of shredders was presumably due to lack of coarse particulate organic matter such as leaf litter, macrophytes, or woody debris (Table 2). Community structure at this site is in accord with functional group patterns described for natural lotic ecosystems (e.g., Cummins 1973 and 1975; Vannote et al. 1980; Hawkins, Murphy, and Anderson 1982; Minshall, Brock, and LaPoint 1982) in which macroinvertebrate functional group composition is dependent largely upon the size, quantity, and quality of available organic matter. The proportions of invertebrate functional groups (i.e. dominance of collectors) at the Columbus site were similar to those of high-ordered (7 to 12) rivers (Cummins 1975, Vannote et al. 1980). Although the riffles are physically similar to small streams, the presence of large-river macroinvertebrate fauna (such as the chironomids and oligochaetes) can be attributed to the proximity of the habitat to the TTW and Columbus Lake.

#### Comparisons with other natural systems

30. In a preimpoundment survey of the Tombigbee River in 1974, 36 taxa of macroinvertebrates were collected at a site near the present gravel bar (Crossman et al. 1975). The community was dominated by mayflies, dragonflies, caddisflies, and beetles, with moderate numbers of true flies and oligochaetes (Table A7). Eleven of these taxa obtained during the preimpoundment study were collected at the gravel bar in 1985-86. The high species richness in the samples collected from the Tombigbee River in the preimpoundment survey was the result of large numbers of invertebrates, such as stoneflies, mayflies, caddisflies, and certain beetles, that are typically found on or under large rocks. Large rocks, cobble, and snags could be placed at the riffles and would provide habitat for additional species of macroinvertebrates and fishes (see Part V).

31. Seven species of unionid molluscs (*Amblema plicata*, *Elliptio crassidens*, *Fusconaia ebena*, *F. rubida*, *Megalonyx nervosa* (= *gigantea*), *Ellipsaria lineolata*, and *Quadrula metanevra*) were collected in two 1-m quadrats in the 1974 preimpoundment survey of the Tombigbee River (Crossman et al. 1975). All of the unionids were thick-shelled gravel bar inhabitants.

Crossman et al. (1975) reported that the substratum, which consisted of sand and mud, was not suitable for a diverse molluscan community. In areas where gravel did occur, it was usually covered with sand and silt.

32. Macroinvertebrates common at the Columbus gravel bar and the Buttahatchie River include: the oligochaetes *Branchiura sowerbyi* and *Dero nivea*, the Asiatic clam *Corbicula fluminea*, trichopterans (*Cheumatopsyche* sp.), ephemeropterans (*Caenis* sp.), and dipterans in the genus *Glyptotendipes*. With the exception of the genus *Caenis* (which is often found on larger objects such as cobble or rock), macroinvertebrate densities were greater at the Columbus gravel bar than at the site on the Buttahatchie River (Table A8). In addition, frequency of occurrence in quantitative samples was usually higher at the Columbus gravel bar than at the Buttahatchie River. An exception was *Corbicula*, which was found in all samples in the Buttahatchie River but in only 80 percent of the samples from the Columbus site. It is anticipated that this species will become more common at the Columbus gravel bar through time.

33. Macroinvertebrate community composition with respect to functional feeding groups was similar at the Columbus gravel bar site and the natural bar on the Buttahatchie River (Table A9). Both communities were dominated by collectors, with few shredders and scrapers and moderate numbers of predators. Presumably there are few shredders at the gravel bar because there is little coarse particulate organic matter (Table 2). Many of the species present at the Columbus gravel bar are cosmopolitan species that probably originated in the riprapped flume or Columbus Lake. Major invertebrate groups that are common to Mississippi and Alabama streams but are not at the habitat include: Megaloptera (Corydalidae and Sialidae), Coleoptera (Elmidae, Psephenidae), and Odonata or dragonflies. The trichoptera, ephemeroptera, and diptera are still poorly represented in terms of species richness. It is possible that as some of these other species colonize the site, they will replace taxa that were common during the first 2 years.

34. The habitat shows an insect community typical of very early stages of succession; i.e., the collector functional feeding group is dominant. In time, the collector group will probably decline until it occupies about 50 to 60 percent of the macroinvertebrate biomass. The grazer-feeding group should increase substantially since some small photosynthetic organisms are present and are likely to increase in numbers. The predators are now poorly

represented, although some of these taxa have 3-year life cycles and may be found during subsequent sampling years.

#### Summary

35. Availability of food, natural substrate, and suitable current generally constitute the parameters of primary significance in determining distributional patterns of benthic macroinvertebrates (Cummins 1975). The nature of the currents contribute significantly to macroinvertebrate food availability as well as substrate conditions. Low current velocity brings about deposition of fine organic and inorganic particulate matter, whereas high velocity removes these materials. Macroinvertebrates are often removed or deposited along with these fine sediments. Macrobenthic community composition at the Columbus site was determined by a complex interaction of biotic and abiotic factors. Organisms that initially colonized the site were cosmopolitan forms that originated from the lake, the riprapped flume, or soft substrates of the Tombigbee River. Currently, the substrate contains little or no organic matter, although detritus may probably increase through time.

36. This study is probably most comparable to the study by Minshall, Andrews, and Manuel-Faler (1983), in which the North Fork of the Teton River, severely damaged by dam failure and subsequent dewatering for repairs, provided an excellent opportunity to study primary succession. In their study, macroinvertebrate densities recovered in about 375 days, but diversity and trophic structure had not fully returned to previous conditions in 3-1/2 years. Successional patterns are dependent on a number of interacting factors such as extent and season of disturbance, proximity of colonizers, and organismal interactions (Fisher 1983). Minshall, Andrews, and Manuel-Faler (1983) cite several studies in which organisms rapidly colonized (days to weeks) sites that were close to dense macroinvertebrate communities. The habitat at Columbus is unique because the riffles were constructed from barren substrates. Also, discharge is constant, and the epilimnial release from Columbus Lake provides suspended particulates (e.g., plankton) that are available to collector-gatherer and collector-filterers. Based on observations by Minshall, Andrews, and Manuel-Faler (1983), succession of this man-made habitat may require at least 3 years.

37. Information obtained on colonization rates and invertebrate community composition at the Columbus site can be used to evaluate effects of water resource development in large waterways. These data can be used to judge the

success of this man-made habitat and how it differs from natural systems. Although gravel is frequently placed in lakes as spawning habitat for fishes, its use in rivers for macroinvertebrates is uncommon. This project was initiated primarily to investigate techniques for constructing and evaluating man-made riffles; however, similar habitats could be created using material from maintenance dredging operations.

## Fishes

### Background

38. Fishes were compared among three sites: the gravel bar, the riprapped flume below the minimum flow release structure, and the abandoned river channel immediately below the gravel bar habitat (see Figures 3 and 4). The flume below the control structure is approximately 30 m long, 4 m wide, and 0.8 to 1.0 m deep, with water velocities in excess of 1.0 m/sec. Riprap was placed along the sides of the flume to prevent scouring and erosion from high-velocity water.

### Community composition

39. A total of 42 species of fishes comprising 10 families were collected from the gravel bar and adjacent sites (Table A10). Thirty-nine species were found over the gravel bar, twenty-five were found in the channel downriver of the habitat, and sixteen were found in the flume. Common taxa included shad, white crappie, bluegill, orangespotted sunfish, largemouth bass, and minnows. The crystal darter, listed as endangered in the State of Mississippi, was collected once in October 1985. Darters were uncommon and collected only at the gravel bar; however, intensive searching using seines could yield additional species (see Part V). The blue sucker was collected on several occasions in the flume directly below the minimum flow release structure.

40. Species richness was significantly ( $p < 0.05$ ) higher at the gravel bar (13 to 24) than at the riprapped flume (8 to 13) or the river channel immediately below the habitat (11 to 16, see Figure 14). Except for the river channel, species richness was highest in May and lowest in December. In the spring, adults ascend streams to spawn (Becker 1983, Pflieger 1975) and are probably attracted to the gravel and flowing water at the habitat. Furthermore, the flume is essentially a tailwater habitat that can attract fishes by

influencing food availability (Walburg, Kaiser, and Hudson 1971) and physical and chemical characteristics (Edwards et al. 1984, Jacobs and Swink 1983).

41. Relatively large individuals (carp, suckers, largemouth bass, catfish, and drum) were collected in the flume above the habitat. These species are often found in high-velocity water, where they feed on tailwater drift (Walburg, Kaiser, and Hudson 1971). Juveniles are probably unable to tolerate the high-velocity water in the flume and are restricted to downstream areas.

42. The appearance of obligate riverine fishes at the gravel bar, such as darters and certain minnows, exemplifies the contribution that this habitat makes to maintaining riverine fish populations in an altered large river habitat. The presence of the blue sucker, which is listed as rare in the United States (Becker 1983), as well as the crystal darter, considered to be endangered by the State of Mississippi, indicates that this habitat contributes to the long-term survival of uncommon species. In addition, it supports a diverse and dense community of sport, commercial, and riverine fishes.

#### Density estimates

43. Density ( $\pm$  standard error) at the gravel bar, as determined using block nets, was 1,150 fishes/ha in December 1985 and 2,893 fishes/ha in May 1986. Minnows were the dominant group in December (41.6 percent), followed by sunfishes (34.3 percent), crappie (19.2 percent), black bass (1.0 percent), and drum (0.3 percent). In May 1986, a total of 24 species were collected, and estimated densities were 1,310 fishes/ha. Shad dominated in May (45.7 percent), followed by minnows (26.8 percent), sunfishes (13.8 percent), drum (5.6 percent), and other sport and commercial species (8.1 percent).

44. CPM, as determined with electrofishing apparatus, varied considerably among sites and seasons (Figure 15). The highest CPM (11.6) was measured in May at the flume and gravel bar, whereas the lowest CPM (2.4) was observed in August in the river channel. Considering all seasons together, the CPM ( $\pm$  standard deviation) at the river channel ( $5.05 \pm 2.56$ ) was significantly lower than at the gravel bar ( $10.2 \pm 1.67$ ) or flume ( $8.15 \pm 2.74$ ) (Table 8). Gizzard and threadfin shad were the dominant species at all sites. Minnows, shiners, and darters were the second most dominant group at the gravel bar, and their CPM was significantly higher than at the other two sites. Drum and catfish were collected in significantly higher numbers in the flume than at the gravel bar or the river channel. Sunfishes were fairly common at all sites and

comprised approximately 20 percent of the total catch. Crappie were most common in the river channel and were relatively uncommon in the shallow water in the riffles or the flume.

45. Fishes collected at the gravel bar, particularly sunfishes, crappie, carp, and suckers, were smaller than those at the flume or river channel. Mean lengths of sunfishes, black bass, and carp/suckers were significantly higher ( $p < 0.05$ ) at the riprapped flume than at the other two sites (Table 9). However, mean lengths of shad, gar, and bowfins were significantly higher at the river channel than at the other two sites.

46. Pennington et al. (1981) studied bendways in the Tombigbee River before completion of the waterway. Big Creek Bendway had been isolated from the main river at the time of their study and was beginning to exhibit lakelike conditions. The Columbus gravel bar is similar in depth and substrate to conditions in the Big Creek Bendway before completion of the TTW. Percent occurrence of sport and commercial fishes, as well as minnows and shiners, was approximately the same at both locations (Figure 16). However, in the present study, the Columbus River channel had a higher percentage of sport fishes than reported from Big Creek Bendway. It is likely that sport fishes are attracted to the Columbus site because of the presence of the flume, which produces conditions similar to a tailwater below a reservoir. High macroinvertebrate biomass below dams has been attributed to improved plankton food supplies, enhanced periphyton, and stabilized discharges (Pett 1985).

47. Hairston Bendway was also sampled during the study by Pennington et al. (1981); however, it had not been cut off from the main river and exhibited riverine conditions. Fishes at this bendway were similar to the gravel bar. Both sites had a higher percentage of minnows and shiners than did the more lentic Big Creek Bendway or the Columbus River channel.

48. The use of artificial gravel bars to provide spawning and rearing habitat for coldwater species, such as trout and salmon, is a successful management technique in the Western United States (Bell 1986). In addition, gravel substrate has been used to restore biota in warmwater streams (Edwards et al. 1984). Total fish density at the gravel bar (1,100 to 2,900 fishes/ha) was lower than most estimates ( $>3,000$  fishes/ha) from natural streams with riffles (Kelly, Catchings, and Payne 1981; Schlosser 1985). However, the habitat at Columbus exhibits similar species composition as those in smaller

streams with pool-riffle sequences. The gravel bar habitat, minimum flow release structure, and flume below Columbus Lake provide conditions that maintain a unique assemblage of aquatic organisms in a river altered by water resource development.

## PART IV: SUMMARY

### General

49. A pool-riffle habitat was constructed in an abandoned channel of the Tombigbee River near Columbus, Miss. The habitat is located below a minimum flow release structure in Columbus Dam, which releases about 5 m<sup>3</sup>/sec of surface water from Columbus Lake.

50. The habitat was constructed with 24,000 m<sup>3</sup> of 2- to 80-mm gravel and consists of two 60-m-long riffles separated by a short pool. The gravel constricts the river channel and increases water velocity in the riffles to 50 cm/sec and provides substrate for aquatic organisms. The riffles are 46 m long and 24 m wide with a maximum depth of 1 m.

51. The habitat, completed in March 1985, was constructed to provide sources of food and cover for aquatic invertebrates and fishes that require flowing, shallow water and gravel substrate. After 2 years in place, there are no sediment accretion and little erosion. Grasses, herbs, sycamore sprouts, and the water willow (*Justica americana*) have colonized exposed portions of the bar.

52. From June 1985 through late fall of 1986, scientists from the WES evaluated physical and biological conditions at the habitat. Substrate samples for invertebrates, particle-size analysis, and organic content were collected in June and October of each year. Fish collections were made in October and December 1985 and in May and August 1986.

### Physicochemical Conditions

53. Water quality at the habitat is influenced by epilimnetic releases from Columbus Lake. Water temperatures range from 4° to 32° C; dissolved oxygen values are often at 100-percent saturation. The water is moderately hard, and dissolved phosphorus and nitrogen are usually less than 0.1 mg/l.

54. The substrate consists of medium to coarse gravel with little sand or silt. In general, the upper depth fraction is composed primarily of gravel while the lower fraction is a gravel-sand mixture. After nearly 2 years in place, the substrate has not armored, and bottom material is relatively unconsolidated. Less than 5 percent of the sediments are particulate organic

matter; there have been no significant changes in this parameter since the habitat was constructed.

55. The bottom profile of both riffles has varied slightly since the habitat was constructed. Because the gravel is unconsolidated, bottom profiles have changed slightly since the habitat was constructed. However, this has not affected its use by aquatic organisms.

#### Macroinvertebrates

56. Petite Ponar samples for invertebrates were made in June and October 1985-86. In 1985, a total of 15 samples for invertebrates were collected from each riffle. In 1986, five quantitative samples, in addition to qualitative collections, were obtained from each riffle. Macroinvertebrates were identified to the lowest possible taxon, and total biomass estimates were made by family.

57. Colonization by invertebrates at the gravel bar was rapid. After 3 months, 19 to 21 taxa were identified, and estimated densities were 3,496 and 2,868 individuals/m<sup>2</sup> at Riffles I and II, respectively. The fauna was dominated by oligochaetes and chironomid larvae; both groups comprised about 63 percent of the community.

58. By October 1985, approximately 8 months after the habitat had been constructed, more than 40 macroinvertebrate taxa had been identified at the site. Total density of macroinvertebrates was estimated at 11,094 and 9,646 individuals/m<sup>2</sup> at Riffles I and II, respectively. Total biomass was 0.6610 and 0.5846 mg/m<sup>2</sup> AFDW, respectively. A sessile filter-feeding invertebrate *Umatella gracilis*, which was in very low densities in June, dominated the habitat in October. Average density for this species was 144,614 stalks/m<sup>2</sup>, and ash free biomass was estimated at 867.7 mg/m<sup>2</sup>.

59. In October 1986, the last collection date for invertebrates, approximately 69 taxa of invertebrates were identified. Densities at Riffles I and II were estimated at 17,949 and 10,982 individuals/m<sup>2</sup>, respectively. Total biomass of invertebrates was estimated at 15.5110 and 4.3290 mg AFDW/m<sup>2</sup> at Riffles I and II, respectively.

60. Approximately 80 taxa of invertebrates have been identified at the gravel bar habitat. Chironomidae dominated the numbers (96.0 percent) in samples collected in June 1985, but declined to 49.6 and 5.6 percent by October

darters were collected at the gravel bar. The blue sucker, considered to be uncommon in the Tombigbee River, was found in the flume.

67. Fish abundance was usually higher at the gravel bar than at the channel or flume. Maximum fish abundance at both the gravel bar and flume was 11.6 CPM in May 1986 and 8.5 CPM at the river channel in December 1985. Shad dominated the catch at the gravel bar (43.2 percent) as well as all other sites. At the gravel bar, minnows and darters were the second most abundant group (23.8 percent), followed by sunfishes (19.8 percent), and crappie (5.5 percent).

68. Significantly smaller sized fishes were found at the gravel bar (mean length = 94 mm) than at the flume (mean length = 188 mm), or river channel below the habitat (mean length = 179 mm). The gravel bar is an important habitat for minnows and juvenile centrarchids while larger individuals are found in the flume and river channel.

69. Estimated fish densities at the Columbus gravel bar (1,100 to 2,900 fishes/ha) were not as high as recorded values from natural riffles (>3,000 fishes/ha). However, lack of large instream cover (snags, undercut banks, large cobble, etc.) probably limits the population.

70. The fish assemblage at the Columbus gravel bar is similar to that in the bendways of the Tombigbee River before completion of the waterway. However, more sport fishes were found at the Columbus site than at other bendways with similar physical conditions. The gravel bar and adjacent sites provide habitat for sport as well as riverine species of fishes.

1986 because of the increase of biomass and numbers of *Corbicula*, a comparatively large bivalve that lives for several years. The macroinvertebrate fauna is dominated both in numbers and biomass by collectors (>90 percent), with relatively few numbers of shredders, scrapers, and predators.

61. With respect to total density and total biomass of macroinvertebrates exclusive of the Asiatic Clam *Corbicula fluminea*, there were few significant (at the 0.01 level) differences in biomass or density between June 1985 or October 1986. Conversely, *C. fluminea* exhibited dramatic increases in biomass during the study period.

62. However, there were significant differences in density and biomass of most invertebrate taxa between the June and October sampling periods of each year. This was related more to seasonal changes and not so much to gradual colonization by these organisms through time.

63. There was a significant difference in density and size distribution of *Corbicula* in the 0- to 13-cm and 13- to 26-cm depth strata. Juvenile *Corbicula* had settled into the deeper sediments; however, there were a greater number of individuals in the upper layer. Presumably, juveniles moved into lower depths where the particles were smaller and more stable.

### Fishes

64. Species richness and relative abundance (catch per unit effort) of fishes were determined on a seasonal basis using electrofishing apparatus. Fishes were collected at the gravel bar, the flume directly below the minimum release structure, and the abandoned channel of the river below the habitat. Block nets were also placed at the up- and downstream sections to estimate fish density (total number of fishes per unit area).

65. Species richness was highest at the gravel bar (13 to 24 species), followed by the river channel below the habitat (11 to 16 species) and the flume below the minimum flow release structure (8 to 13 species). A total of 42 species were collected in the study area, 39 were found at the gravel bar, 25 were found in the river channel, and 16 were obtained in the flume.

66. Unusual or rare species of fishes were periodically collected at the habitat. The crystal darter, listed as endangered by Mississippi and other Southeastern States, was found at the habitat. Two other species of

## PART V: RECOMMENDATIONS

71. Modifications could be incorporated in the gravel bar that would attract additional riffle-dwelling species of fishes and invertebrates. In addition, uncommon or endangered species of fishes or mussels could be relocated to the site for protection and study. The following are recommended:

- a. Boulders could be placed in the riffles of the habitat to create more interstitial space for spawning, feeding, and temporary velocity shelters for darters and madtoms. In addition, boulders would create high-velocity zones needed by most darters. These fishes have strict habitat requirements, and additional heterogeneity in the substrate would increase the diversity of these genera (Douglas 1974; Pflieger 1975; Becker 1983; Page 1983). For example, the frecklebelly madtom (*Noturus munitus*), listed as endangered by Mississippi, was collected behind a clump of rocks and debris in a riffle on the Buttahatchie River. The frecklebelly madtom would likely inhabit the artificial gravel bar, especially if larger rocks were present.\*
- b. The pool between the two riffles at the artificial gravel bar would be improved if trees or shrubs were planted along the shoreline. This would attract more cover-oriented sport fishes, such as largemouth bass, that utilize cover for feeding and resting (Stroud and Clepper 1975; Gore 1979; Angermeier and Karr 1984). Certain insects (i.e. *Corydalus* sp. and *Sialis* sp.) use overhanging vegetation as ovaposition sites.
- c. Large flat rocks could be placed in one or both riffles. In addition to providing cover for darters and madtoms, they would be used by aquatic insects such as mayflies and caddisflies. They also serve to retain leaves, twigs, and other detritus, thereby increasing trophic diversity.
- d. Unusual or uncommon species of fishes could be introduced to the habitat. Candidate species include: frecklebelly madtom (*Noturus munitus*), freckled darter (*Percina lenticula*), fluvial shiner (*Notropis edwarddraneyi*), black madtom (*Noturus funebris*), rock darter (*Etheostoma rupestri*), blackwater darter (*Etheostoma zoniferum*), and the crystal darter (*Ammocrypta asprella*), which has been collected at the site.
- e. An endemic mussel (*Epioblasma penita*, southern combshell mussel, formerly known as the penitent mussel), proposed for listing as endangered, is found in the Buttahatchie River. This species could be transplanted to the Columbus gravel bar. Transplanting uncommon, rare, or possibly endangered species would not be done without appropriate coordination with State and Federal agencies.

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\* Personal Communication, 1986, Neil Douglas, Northeast Louisiana University, Monroe, La.

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Table 1

Physicochemical Data from the Gravel Bar on the Tombigbee River and a Comparative Site on the Buttahatchie River (June 1985-October 1986)\*

Parameter	Tombigbee River				Buttahatchie River			
	Min	Max	Mean	N	Min	Max	Mean	N
Alkalinity (as $\text{CaCO}_3$ )	38	58	48	10	7	50	29	4
Conductance ( $\mu\text{m}/\text{cm}$ )	125	330	172	10	26	40	34	4
pH	7.2	8.2	7.8	6	6.5	7.0	6.7	4
Water temperature (Celsius)	4	32	22	10	10	28	20	5
Percent oxygen saturation	92	100	96	11	79	100	92	8
Total hardness (as $\text{CaCO}_3$ )	59	156	98	10	30	36	33	4
Calcium hardness (as $\text{CaCO}_3$ )	7	126	63	10	19	26	22	4
Turbidity (NTU)	7	109	46	10	15	62	34	4
Total phosphorus	<0.1	--	--	6	<0.1	--	--	3
Orthophosphate	<0.1	0.1	--	7	0.01	0.02	0.02	3
Total Kjeldahl nitrogen	0.4	10.6	2.7	7	0.14	0.21	0.18	3
Nitrate nitrogen	<0.1	1.7	--	7	0.19	0.20	0.20	3
Total organic carbon	5.2	10.6	7.2	6	2.9	3.6	3.2	3
Dissolved organic carbon	2.0	7.1	5.0	6	2.5	3.1	2.8	3
Particulate organic carbon	0.9	4.9	2.2	6	0.2	0.5	0.4	3
Suspended particulates	2.4	16.3	8.1	6	--	--	--	--

\* All measurements in milligrams per litre unless otherwise noted.

Table 2  
Percentage Organic Matter in Sediments Collected  
from the Columbus Gravel Bar

	<u>June 1985</u>	<u>October 1985</u>
Riffle I	1.04	0.80
Riffle I	1.12	0.76
Pool	1.02	0.96

Table 3  
Numbers of Macroinvertebrate Taxa at the Columbus Gravel Bar  
Habitat, 1985-86

<u>Location</u>	<u>1985</u>		<u>1986</u>	
	<u>June</u>	<u>October</u>	<u>June</u>	<u>October</u>
Riffle I	19	34	25	38
Riffle II	21	34	24	39
Pool	8	19	23	39

Table 4

## Average Densities for Macroinvertebrates at the Columbus Gravel

Bar Habitat, 1985-86 (No./m<sup>2</sup>)

Location	1985				1986			
	June		October		June		October	
	Ave	SD	Ave	SD	Ave	SD	Ave	SD
<u>Total Macroinvertebrates</u>								
Riffle I	3495.7	1343.6	11094.0	1014.2	4202.3	2081.7	17949.1	7726.6
Riffle II	2867.6	2175.0	9646.3	3434.5	4450.2	1340.9	10982.7	4726.7
Pool	404.5	539.1	2648.8	1014.2	1498.0	965.4	12106.0	6113.1
<u>Total Macroinvertebrates (Without <i>Corbicula</i>)</u>								
Riffle I	3495.7	1343.6	11106.9	2188.7	3955.0	1844.0	1545.3	7542.6
Riffle II	2867.1	2175.0	9657.6	3428.5	4347.0	1288.9	9797.4	4259.9
Pool	404.7	539.1	2651.9	1015.4	1283.6	450.6	9842.2	7514.5
<u><i>Corbicula</i></u>								
Riffle I	11.5	25.6	361.6	354.0	51.6	70.2	6646.9	5933.6
Riffle II	14.4	35.2	525.2	548.5	103.2	103.6	1730.6	785.2
Pool	0.0	--	292.7	273.6	68.8	65.2	981.2	254.0
<u><i>Glyptotendipes</i> sp.</u>								
Riffle I	2433.8	1000.9	9706.3	2012.1	867.6	337.8	7172.1	3697.5
Riffle II	2032.0	1621.9	8317.3	2640.2	1032.6	917.1	3159.9	1960.0
Pool	249.7	380.7	768.7	74.2	59.8	87.0	6104.5	3779.9
<u>Naididae</u>								
Riffle I	2.9	11.1	450.6	349.2	309.6	198.0	447.6	199.1
Riffle II	28.4	39.4	335.8	259.9	576.6	524.0	1412.0	458.1
Pool	0.0	--	146.3	151.0	189.2	178.9	2204.2	1690.9
<u>Tubificidae</u>								
Riffle I	14.3	55.5	37.3	70.6	301.4	232.0	68.9	72.0
Riffle II	5.7	15.1	11.5	25.5	542.4	404.5	292.7	214.0
Pool	0.0	--	51.6	56.1	86.0	100.8	387.4	525.5
<u>Trichoptera</u>								
Riffle I	71.7	60.1	117.5	177.6	43.0	43.0	1782.2	1285.5
Riffle II	31.5	50.0	295.3	262.0	25.8	38.5	559.6	241.6
Pool	8.6	19.2	86.0	145.8	17.2	38.5	172.2	125.5

Table 5  
Average Biomass (g) Values for Macroinvertebrates at the Columbus  
Gravel Bar Habitat, 1985-86

Location	1985		1986	
	June	October	June	October
<u>Total Macroinvertebrates</u>				
Riffle I	0.2029	0.6610	0.3300	15.5110
Riffle II	0.2018	0.5846	0.2018	4.3290
Pool	0.0561	0.0988	0.0923	2.7090
<u>Total Macroinvertebrates (Without Corbicula)</u>				
Riffle I	0.2024	0.6102	0.3145	2.29
Riffle II	0.1863	0.5413	0.1838	0.54
Pool	0.0561	0.0919	0.0673	0.56
<u>Corbicula</u>				
Riffle I	0.0155	0.0508	0.0156	13.22
Riffle II	0.0155	0.0433	0.0180	3.7960
Pool	0.0000	0.0069	0.0250	2.1502
<u>Chironomidae</u>				
Riffle I	0.0498	0.5465	0.0845	0.5320
Riffle II	0.1786	0.4917	0.1158	0.2973
Pool	0.0064	0.0862	0.0401	0.4280
<u>Naididae</u>				
Riffle I	0.0001	0.0259	0.0073	0.0050
Riffle II	0.0006	0.0106	0.0105	0.0282
Pool	0.0000	0.0112	0.0082	0.0441
<u>Tubificidae</u>				
Riffle I	0.0007	0.0059	0.1343	0.0028
Riffle II	0.0001	0.0003	0.0568	0.0117
Pool	0.0000	0.0051	0.0133	0.0155
<u>Trichoptera</u>				
Riffle I	0.0089	0.0160	0.0202	0.2354
Riffle II	0.0022	0.0160	0.0043	0.0757
Pool	0.0091	0.0189	0.0034	0.0246

Table 6  
Percentage Composition of Major Macroinvertebrate Groups at the  
Columbus Gravel Bar Habitat, 1985-86

<u>Group</u>	<u>1985</u>		<u>1986</u>	
	<u>June</u>	<u>October</u>	<u>June</u>	<u>October</u>
	<u>Percentage Density</u>			
Chironomidae	96.01	83.67	71.20	49.66
Naididae	0.47	3.76	10.80	8.90
Tubificidae	0.30	0.42	9.34	1.75
Trichoptera	2.16	1.66	0.87	5.50
<i>Corbicula</i>	0.38	4.76	2.25	20.49
Others	0.68	5.74	5.53	13.70
	<u>Percentage Biomass</u>			
Chironomidae	80.46	76.55	38.59	5.58
Naididae	0.13	3.22	4.15	0.36
Tubificidae	0.19	0.77	32.52	0.13
Trichoptera	4.28	3.04	4.44	1.49
<i>Corbicula</i>	3.84	11.96	7.45	90.90
Others	11.49	5.07	12.86	1.54

Table 7  
Macroinvertebrate Density and Biomass (mg) Estimates  
at Natural Riffles

<u>River, Location, Characteristics, and Sampling Period</u>	<u>Abundance No./m<sup>2</sup></u>	<u>Biomass mg AFDW/m<sup>2</sup></u>	<u>Reference</u>
Pine River, Mich. natural, trout stream, Jun-Oct	61.625	1.395	Barber and Kevern 1973
Mink Creek, Idaho natural, trout stream annual	6.907* 21.487**	10.811 26.502	Minshall 1981 Minshall 1981
River Wye, United Kingdom natural Jul	32.766	--	Pett 1985
River Elan, United Kingdom regulated Jul	15.206		Pett 1985
Buttahatchie River, Miss. natural, warm water Aug	0.838	--	Miller, King, and Glover 1983

\* Sediments = cobble and boulder.

\*\* Sediments = pebble and gravel.

Table 8  
Functional Feeding Group Compositions on  
20 June and 16 October 1985\*

<u>Functional Group</u>	<u>No. Taxa</u>		<u>Percent Density</u>		<u>Percent Biomass</u>	
	<u>June</u>	<u>Oct</u>	<u>June</u>	<u>Oct</u>	<u>June</u>	<u>Oct</u>
Collector	25	40	98.9	94.9	97.9	94.6
Gatherer	19	32	95.8	86.6	88.1	83.8
Filterer	6	8	3.1	8.8	9.8	10.8
Scraper	1	4	0.1	2.5	0.0	3.5
Shredder	0	0	0.0	0.0	0.0	0.0
Predator	5	9	1.0	3.0	2.1	2.2

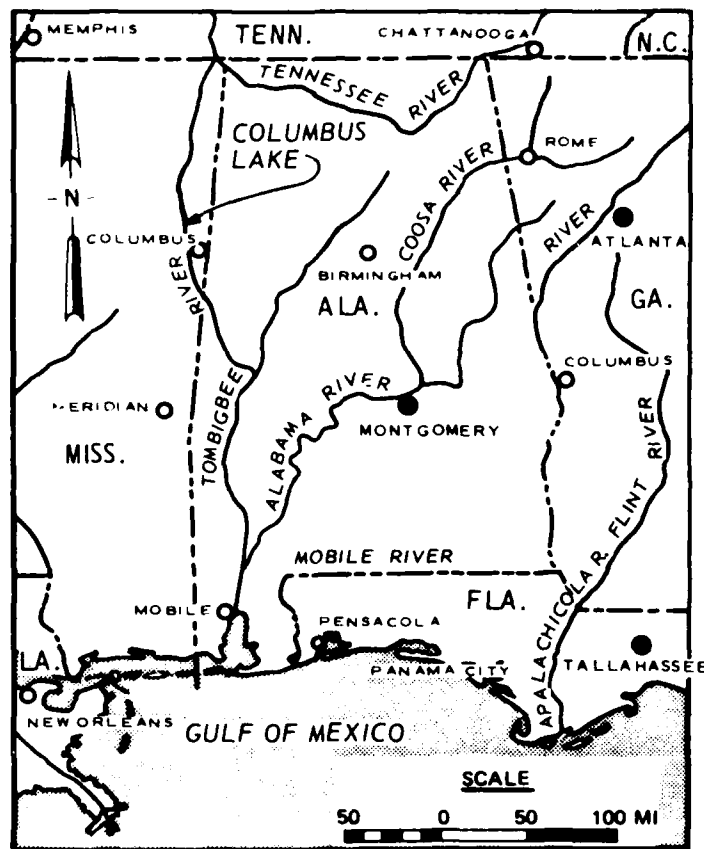
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\* Each data point represents an average for Riffles I and II.

Table 9  
Comparison of CPM and Fish Length Between the Gravel Bar,  
Control Structure, and Bendway\*

<u>Species</u>	<u>Total Catch</u>	<u>Mean CPM</u>	<u>CPM Percent</u>	<u>Mean Length, mm</u>	<u>Length Range, mm</u>
<u>Gravel Bar</u>					
Shad	406	4.4 ± 3.00	43.2	93 ± 67*	20-343
Sunfishes	173	2.02 ± 1.59	19.8	68 ± 27*	26-185
Minnows and darters	221	2.43 ± 1.06*	23.8	63 ± 18*	27-110
Crappie	45	0.56 ± 0.94	5.5	124 ± 49*	34-225
Black bass	31	0.36 ± 0.34	3.5	146 ± 41	84-255
Buffalo	14	0.13 ± 0.21	1.3	365 ± 50	247-446
Drum	12	0.12 ± 0.12	1.2	220 ± 66	139-332
Catfish	2	0.02 ± 0.03	0.2	234 ± 100	163-305
Carp and suckers	14	0.13 ± 0.19	1.3	271 ± 112*	187-619
Gar and bowfins	2	0.02 ± 0.03	0.2	189 ± 221*	33-345
Total fishes	920	10.37 ± 1.70*	100	94 ± 72*	20-619
<u>Control Structure</u>					
Shad	66	2.00 ± 2.31	24.5	61 ± 45*	30-242
Sunfishes	64	1.79 ± 1.54	22.1	109 ± 36*	45-189
Minnows and darters	2	0.04 ± 0.05	0.5	65 ± 14	55-75
Crappie	3	0.09 ± 0.11	1.1	168 ± 104	56-263
Black bass	16	0.59 ± 0.55	7.3	290 ± 102*	145-482
Buffalo	6	0.28 ± 0.37	3.4	393 ± 68	326-524
Drum	45	2.15 ± 2.26*	26.4	276 ± 114	24-495
Catfish	9	0.35 ± 0.25*	4.3	378 ± 140	165-568
Carp and suckers	20	0.85 ± 0.83	10.4	442 ± 93*	289-580
Gar and bowfins	0	0	0	--	--
Total fishes	231	8.15 ± 2.74	100	188 ± 151	24-580
<u>Bendway</u>					
Shad	80	1.01 ± 0.93	19.3	145 ± 58*	20-282
Sunfishes	96	1.16 ± 0.49	22.2	97 ± 37*	20-195
Minnows and darters	45	0.56 ± 0.35	10.7	50 ± 15	14-88
Crappie	88	1.26 ± 2.18	24.1	213 ± 63	66-408
Black bass	16	0.19 ± 0.15	3.6	185 ± 77	71-324
Buffalo	39	0.66 ± 0.77	12.6	369 ± 72	256-721
Drum	3	0.05 ± 0.07	1.0	317 ± 47	263-348
Catfish	1	0.01 ± 0.01	0.2	432 ± 0	--
Carp and suckers	21	0.26 ± 0.17	5.0	337 ± 92*	204-505
Gar and bowfins	5	0.07 ± 0.08	1.3	550 ± 146*	350-700
Total fishes	394	5.05 ± 2.60*	100	179 ± 120	14-721

\* Mean values are expressed as ±1 standard deviation. Asterisk indicates value is significantly different.



VICINITY MAP

Figure 1. The gravel bar habitat is located on the Tombigbee River near Columbus in eastern Mississippi

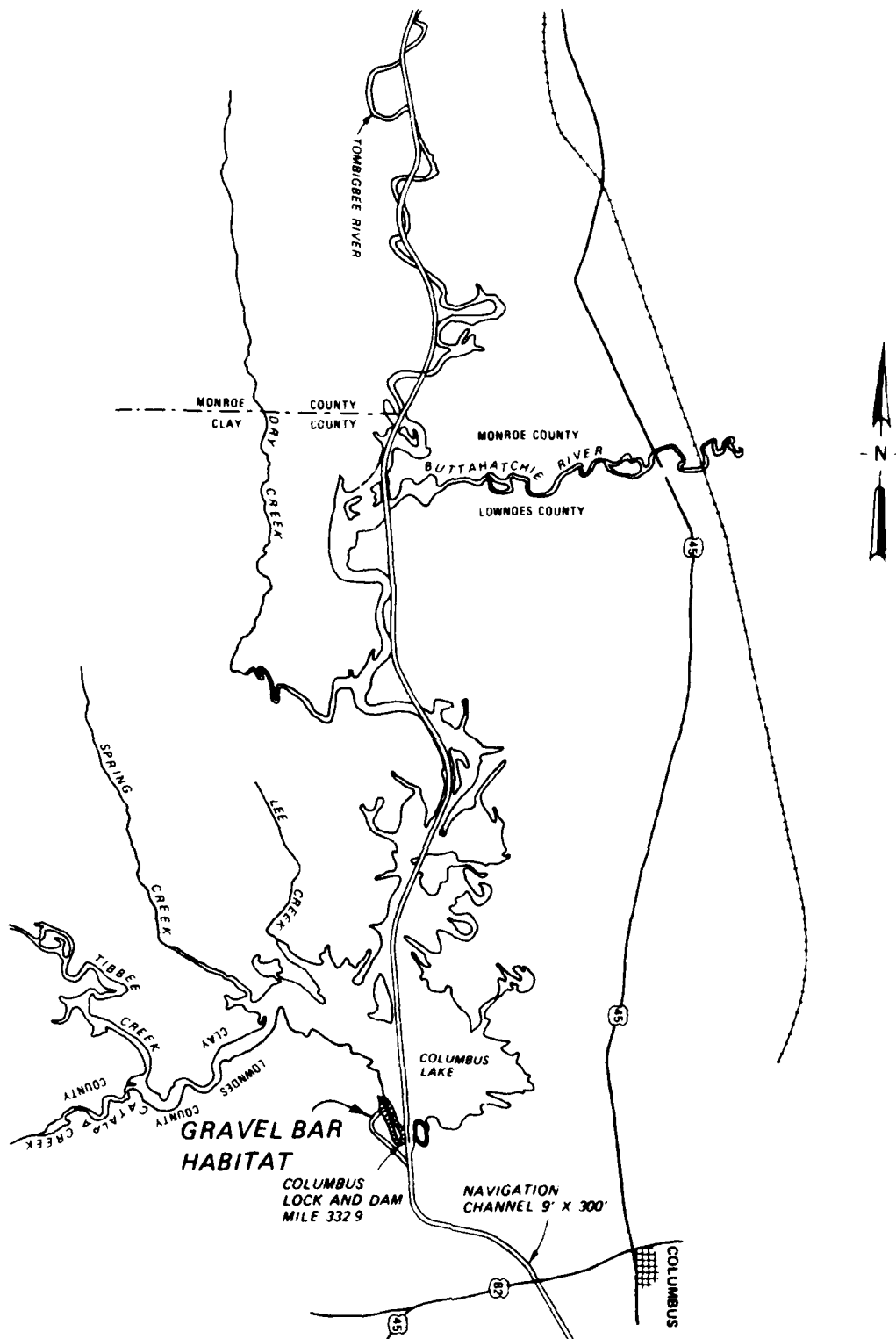


Figure 2. The Tombigbee River and the abandoned channel where the gravel bar habitat is located

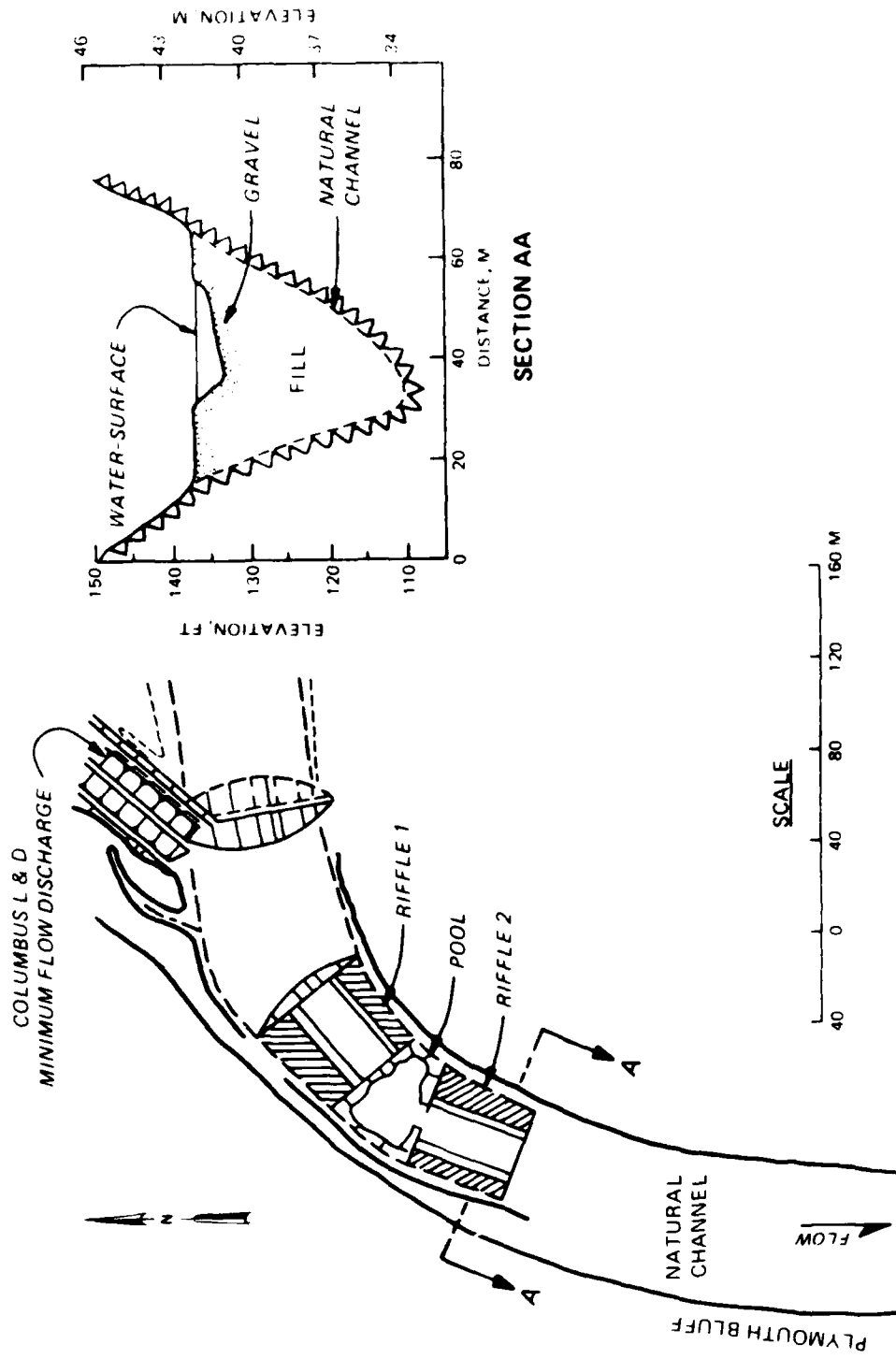


a. Intake structure



b. Water from Columbus Lake flows through the riprapped channel flume and into the upper end of the channel above the habitat

Figure 3. Minimum flow release structure in Columbus Dam (a) and the outfall area directly above the habitat (b)

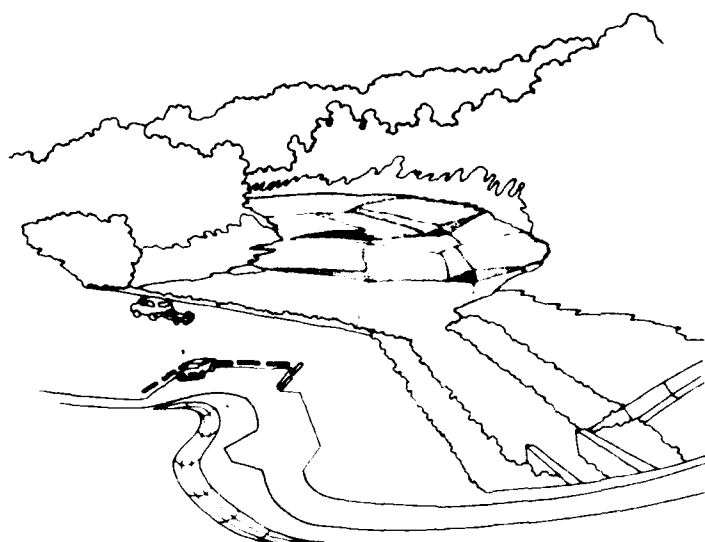


a. Plan view b. Transverse section of the two bars

Figure 4. A plan (a) and transverse (b) diagram of the gravel bar habitat



a. Aerial photograph



b. Drawing of the gravel bars with the minimum flow release structure in the background

Figure 5. An aerial photograph (a) and drawing (b) of the gravel bar habitat near Columbus, Mississippi

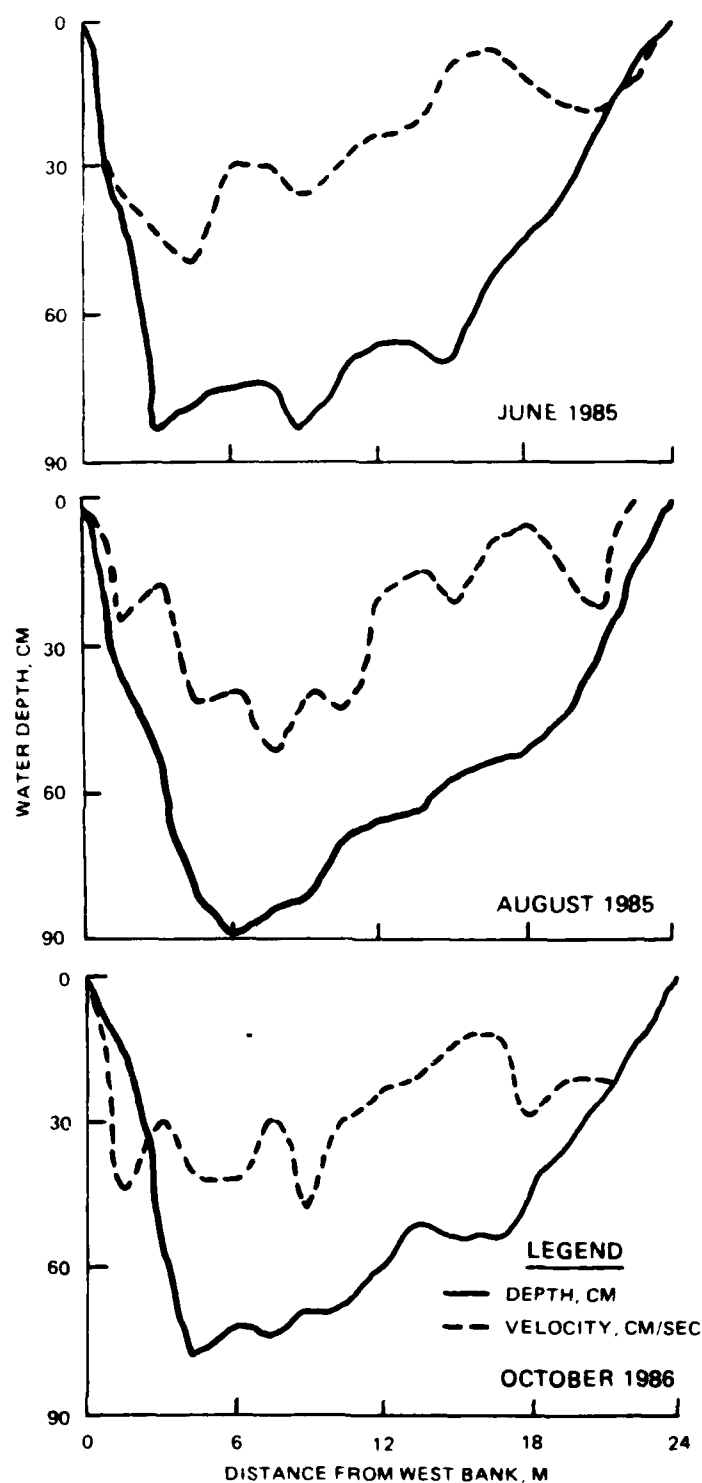


Figure 6. Depth and water velocity profiles for Riffle I in June and August 1985 and October 1986

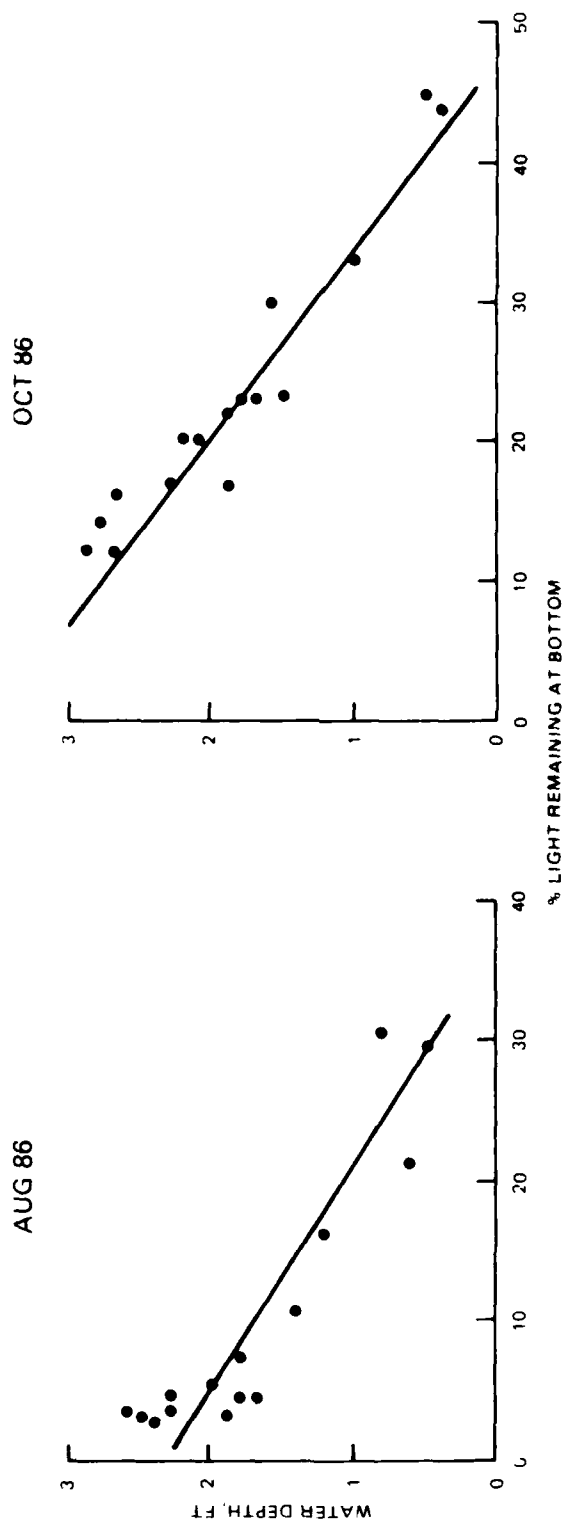


Figure 7. Percentage of incident light at selected water depths in Riffle I of the Columbus gravel bar habitat, August and October 1986

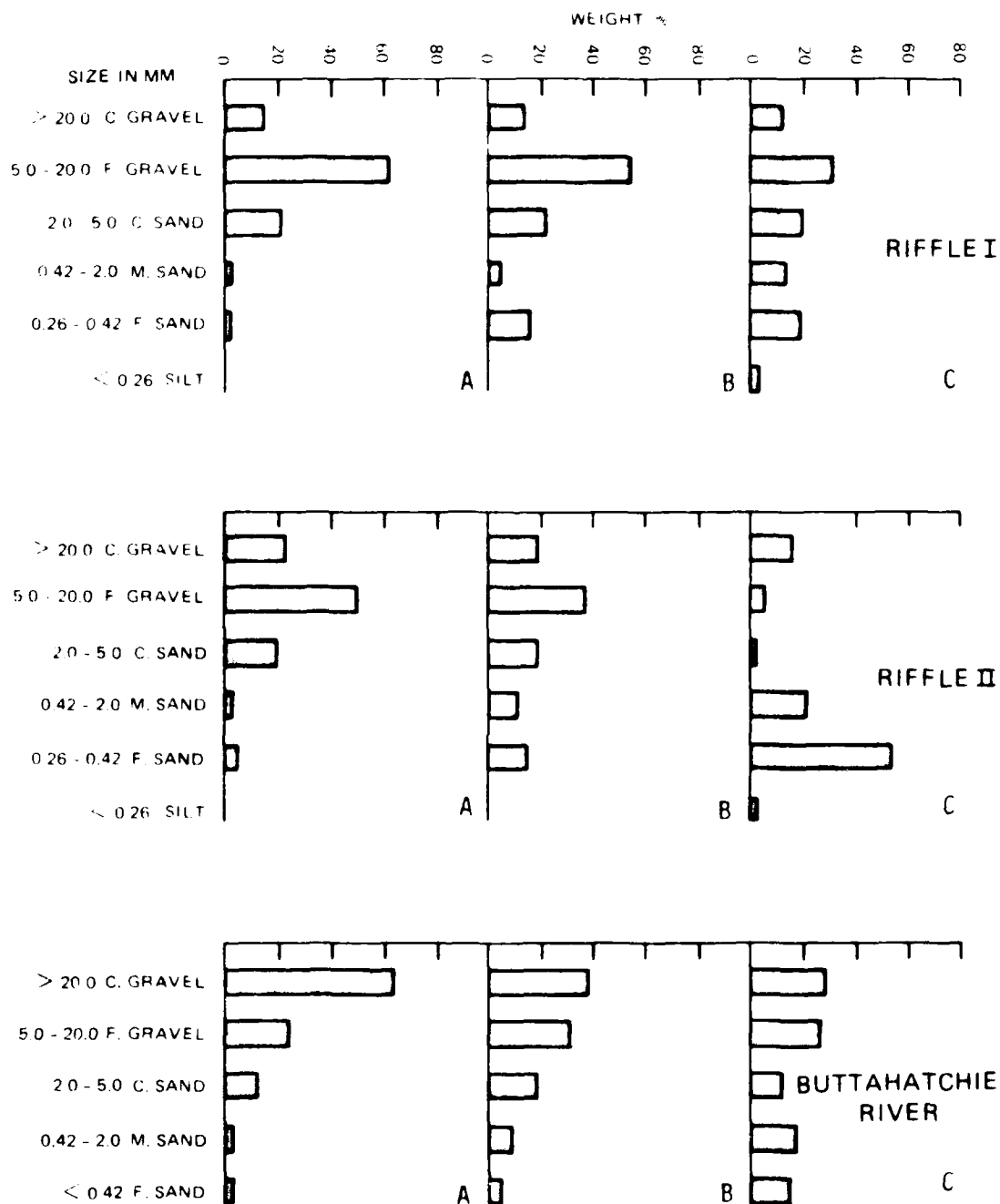


Figure 8. Particle-size distribution of sediments at Riffles I and II (June 1985) and the natural gravel bar on the Buttahatchie River (August 1981). In each series the coarsest (A) and finest (C) material are displayed. The center histogram (B) is an average of either 12 (Buttahatchie River) or 15 (Columbus gravel bar) replicate samples

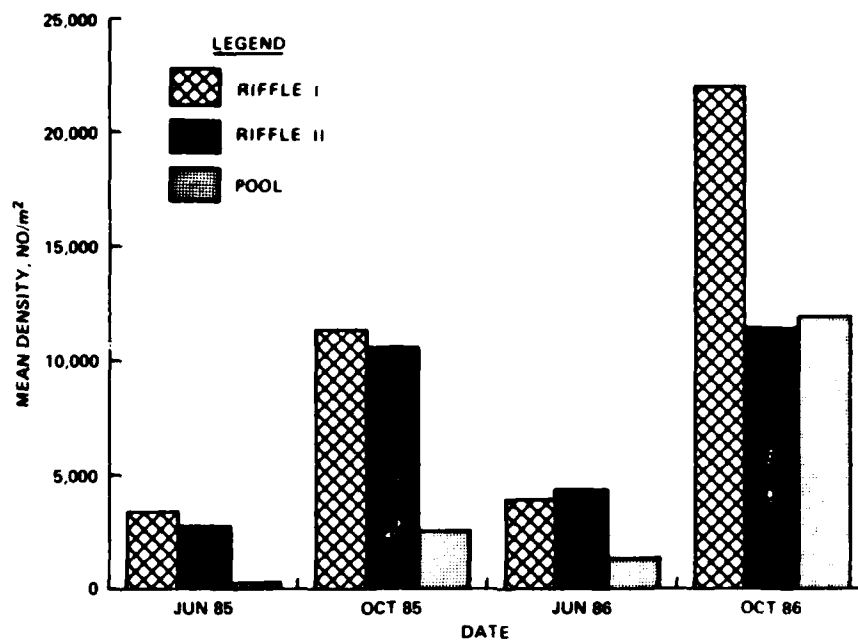


Figure 9. Mean density (number per square metre) of macroinvertebrates from the Columbus gravel bar, 1985-86

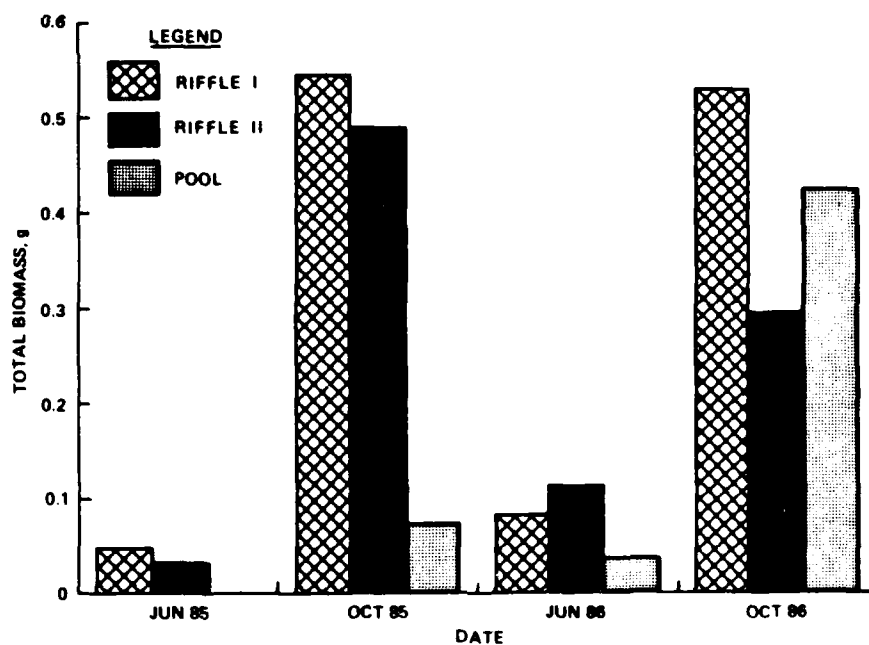


Figure 10. Total biomass (grams per square metre) of chironomidae at the Columbus gravel bar, 1985-86

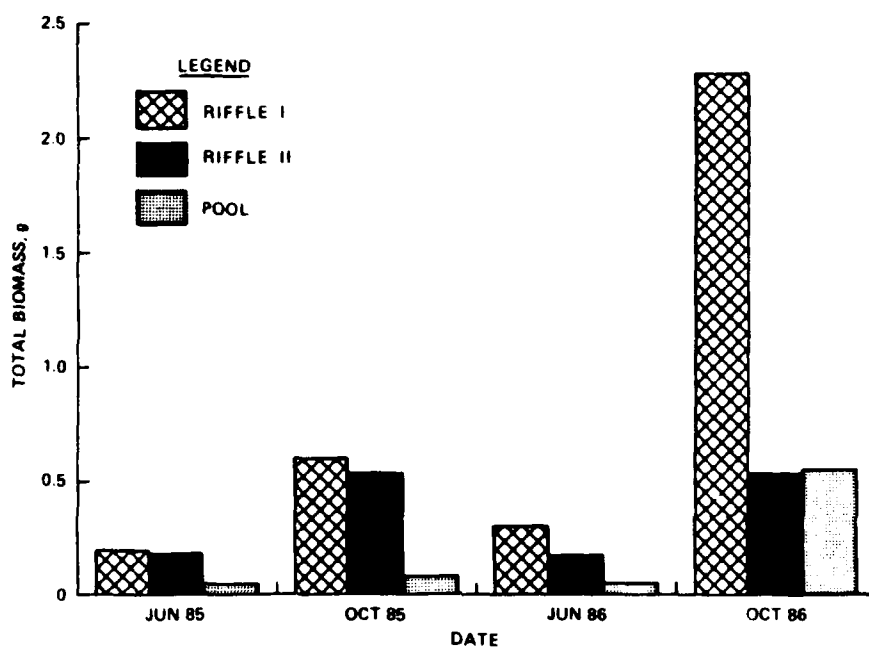


Figure 11. Total biomass of macro-invertebrates (exclusive of *Corbicula fluminea*) at the Columbus gravel bar, 1985-86

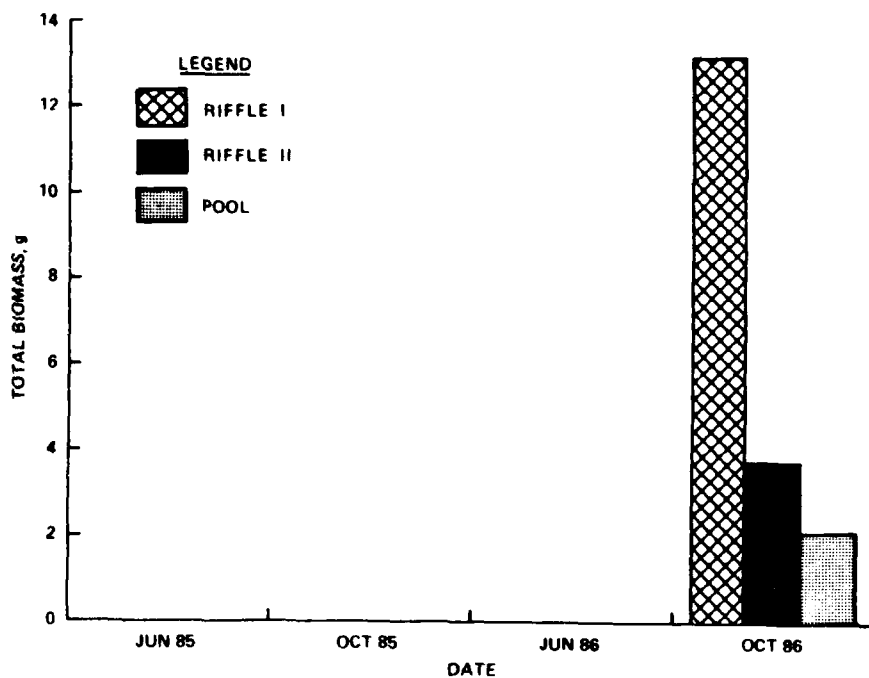


Figure 12. Total biomass of *Corbicula fluminea* at the Columbus gravel bar, 1985-86

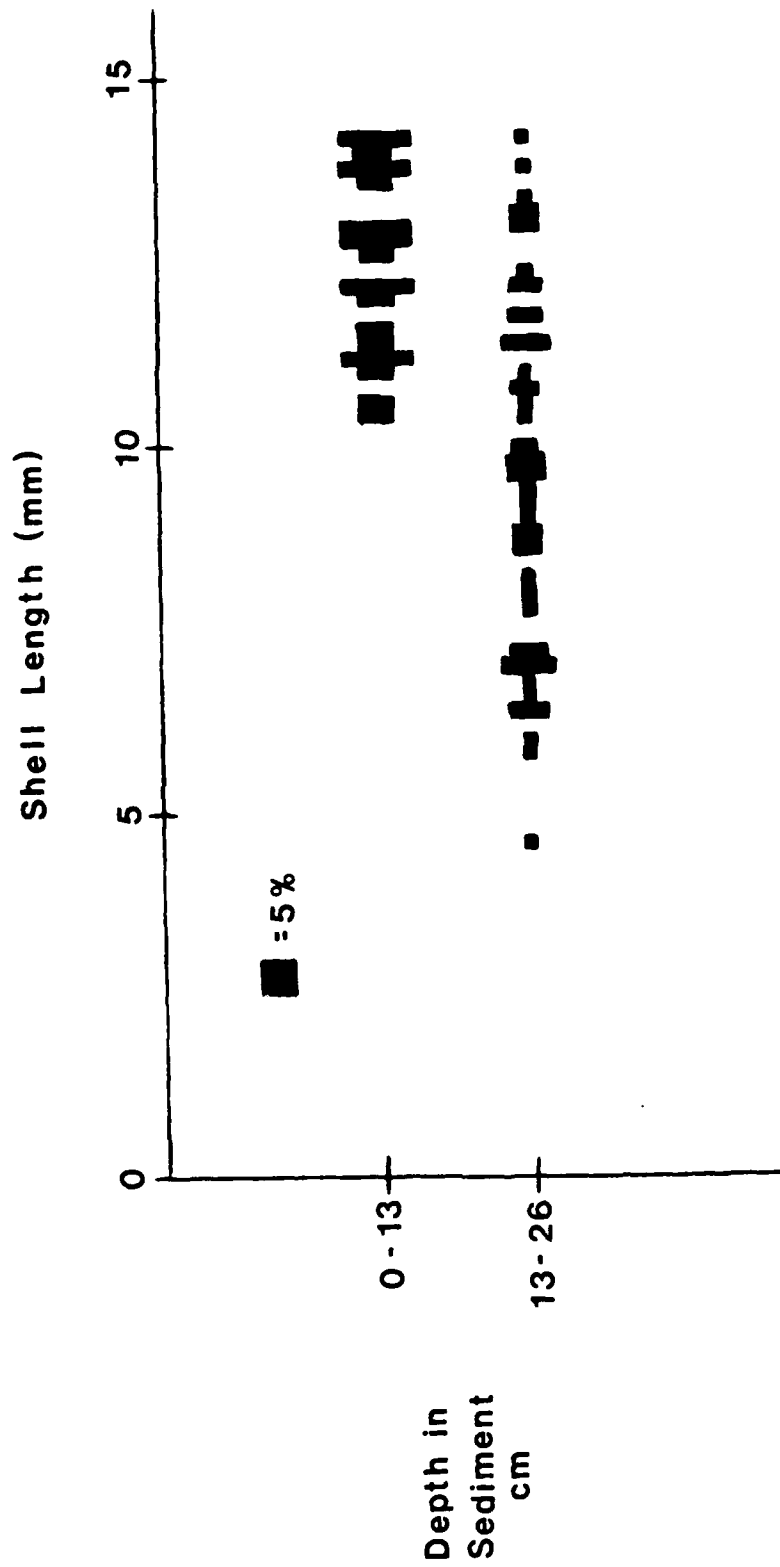


Figure 13. Size distribution of *Corbicula fluminea* at two depth strata at the Columbus gravel bar, 1986

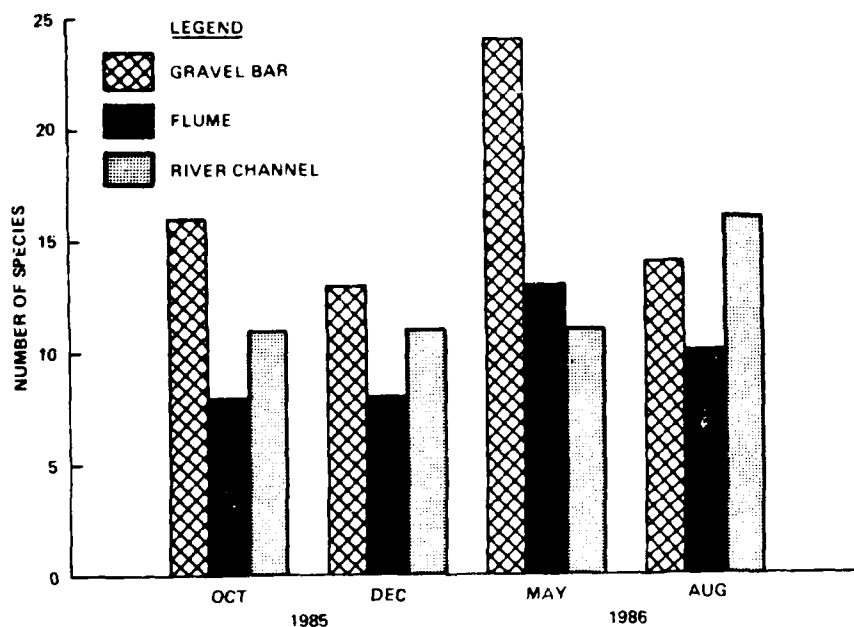


Figure 14. Species richness of fishes at the Columbus gravel bar habitat, 1985-86

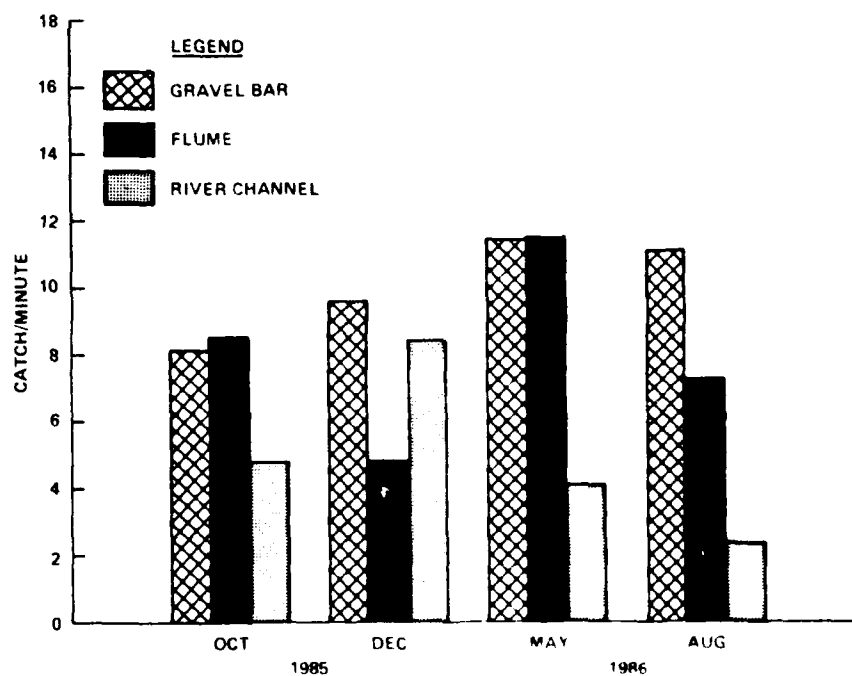


Figure 15. CPM effort for fishes collected at the Columbus gravel bar, 1985-86

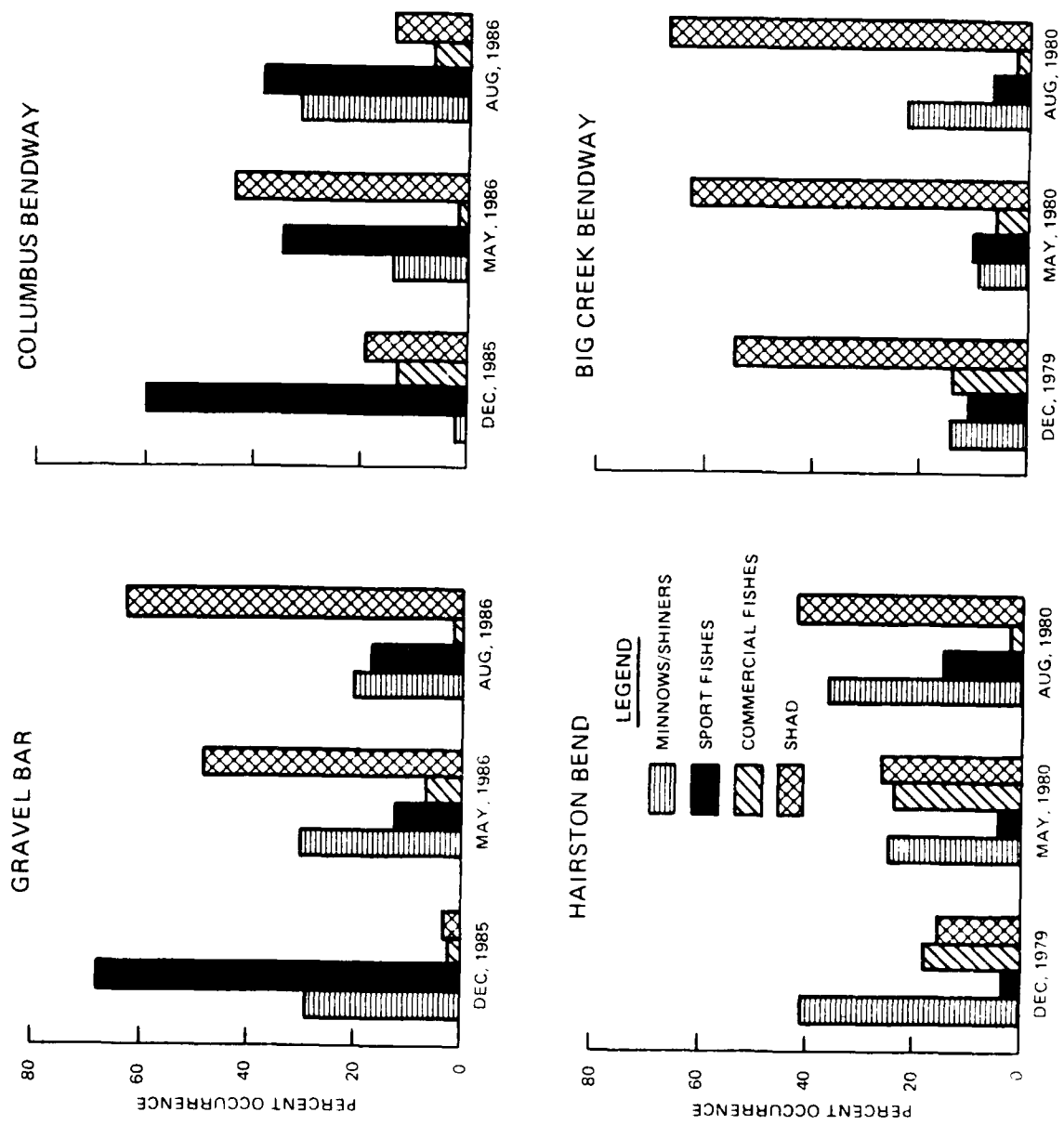


Figure 16. Percent occurrence of sport and commercial fishes and minnows/shiners

APPENDIX A: MACROINVERTEBRATE AND FISHERY DATA FROM THE COLUMBUS GRAVEL  
BAR AND SELECTED COMPARATIVE SITES

Table A1  
Macroinvertebrate Species Present in Quantitative Sediment Samples  
Collected in the Riffles at the Columbus Gravel Bar, 1985-86\*

Phylum	Class	Scientific Name	Trophic Status	1985		1986	
				Jun	Oct	Jun	Oct
Coelenterata		<i>Hydra</i> sp.	P	U	C	U	A
		<i>Cordylophora lacustris</i>	P	-	U	-	A
Platyhelminthes		<i>Dugesia tigrina</i>	S	-	C	C	A
		<i>Dugesia</i> sp.	S	U	C	U	A
Nematode worms				-	U	U	A
Bryozoa		Plumatellidae	CFF	-	U	C	C
		<i>Pottsiella erecta</i>	CFF	-	-	C	C
Entoprocta		<i>Umatella gracilis</i>	CDF	A	A	A	A
Annelida		Hirudinea (leeches)	P	-	-	-	-
		<i>Helobaella triserialis</i>	P	U	U	U	U
	Oligochaeta	<i>Branchiura sowerbyi</i>	CDF	U	U	U	U
		<i>Bratislavia unidentata</i>	CDF	-	U	U	-
		<i>B. bilongata</i>	CDF	-	-	U	-
		<i>Chaetogaster diaphanus</i>	P	-	U	-	U
		<i>Dero digitata</i>	CDF	-	C	-	U
		<i>D. nivea</i>	CDF	-	C	C	A
		<i>D. obtusa</i>	CDF	-	-	C	C
		<i>D. trifida</i>	CDF	U	C	-	-
		<i>Dero</i> sp.	CDF	-	C	U	C
		<i>Limnodrilus mawmeensis</i>	CDF	U	-	-	-
		<i>L. udekemianus</i>	CDF	-	-	-	U
		<i>Nais bretscheri</i>	CDF	-	U	-	-
		<i>N. communis</i>	CDF	-	U	-	-
		<i>N. pardalis</i>	CDF	U	C	U	C
		<i>N. simplex</i>	CDF	U	-	-	U
		<i>N. variabilis</i>	CDF	-	U	-	U
		<i>Pristinella longisoma</i>	CDF	-	-	-	U
		<i>P. osborni</i>	CDF	-	U	U	-
		<i>Pristina leidy</i>	CDF	-	U	-	U
		<i>Ripistes parvita</i>	CDF	-	-	U	-
		<i>Slavina appendiculata</i>	CDF	U	U	-	-
		<i>Specaria josinae</i>	CDF	U	U	U	C
		<i>Stephensoniana tandyi</i>	CDF	-	-	-	U
		<i>Stylaria fassularis</i>	CDF	-	-	C	-
		Tubificidae	CDF	-	U	-	-
		Aelosomatidae	CDF	-	-	-	U
Mollusca	Bivalvia	<i>Corbicula fluminea</i>	CFF	U	A	C	A
	Gastropoda	Ancylidae (limpets)	S	-	C	C	A
		Snails		-	-	U	U
Arthropoda	Crustacea	<i>Asellus</i> sp.	CDF	-	-	C	C

(Continued)

- \* P = predator.  
S = scraper.  
CFF = collector, filter feeder.  
CDF = collector, deposit feeder.  
U = uncommon, in 10 percent or less of the samples.  
A = abundant, collected 90 percent or more of the samples.  
C = common, collected more than 10 but less than 90 percent of the samples.

Table A1 (Concluded)

Phylum	Class	Scientific Name	Trophic Status	1985		1986	
				Jun	Oct	Jun	Oct
Arthropoda (continued)	Insecta	<i>Ablabesmyia janta</i>	P	-	U	-	-
		<i>A. mallochii</i>	P	-	-	U	-
		<i>A. parajanta</i>	P	-	-	U	U
		<i>Chaoborus</i> sp.	P	U	U	-	-
		<i>Chironomus decorus</i> gr.	CDF	-	-	U	-
		<i>Cladotanytarsus mancus</i> gr.	CDF	-	-	U	-
		<i>Cladotanytarsus</i> sp.	CDF	-	U	-	-
		<i>Cricotopus</i> nr. <i>bicinctus</i>	CDF	-	C	-	-
		<i>Cryptochironomus fulvus</i> gr.	P	-	U	C	-
		<i>Dicrotendipes neomodestus</i>	S	-	-	C	C
		<i>D. nervosus</i> Type I	S	-	U	A	A
		<i>D. nervosus</i> Type II	S	-	-	C	C
		<i>Dicrotendipes</i> sp.		-	-	C	C
		<i>Glyptotendipes</i> nr. <i>lobiferus</i>	CFF	A	A	A	A
		<i>Microsectra</i> sp.	CDF	-	-	-	U
		<i>Nanocladius crassicornus</i>	CDF	-	-	-	U
		<i>N. distinctus</i>	CDF	-	C	A	A
		<i>N. minimus</i>	CDF	-	-	-	C
		<i>Orthocladius</i> prob. <i>annectens</i>	CDF	-	-	U	A
		<i>Parachironomus abortivus</i>	P, CDF	-	-	U	-
		<i>P. frequens</i>	P	-	-	U	C
		<i>Phaenopsectra dyari</i>	S	-	-	-	U
		<i>Polypedilum convictum</i>	CFF	-	U	-	U
		<i>P. fallax</i>	CFF	-	-	-	C
		<i>P. illinoense</i>	CFF	-	-	-	U
		<i>Pseudochironomus</i> sp.	CDF	-	-	C	U
		<i>Rheotanytarsus distinctissimus</i> gr.	CDF	-	-	-	U
		<i>Rheotanytarsus eriquus</i> gr.	CFF	-	U	-	U
		<i>Tanytarsus glabrescens</i> gr.	CDF	-	U	-	-
		<i>T. coffmani</i>		-	-	-	U
	Ephemeroptera	<i>Baetis</i> sp.	CDF	U	U	-	-
		<i>Caenis</i> sp.	CDF	U	U	U	
	Odonata	<i>Argia violacea</i>	P	U	-	-	-
	Trichoptera	<i>Agraylea</i> sp.	S	-	U	-	-
		<i>Ceraclea</i> sp.		-	-	-	U
		<i>Cheumatopsyche</i> sp.	CFF	U	C	U	A
		Hydropsychidae	CFF	U	U	-	A
		<i>Cymellus fraternus</i>	CFF	C	C	C	C
		<i>Nectopsyche</i> sp.		-	-	U	-
		<i>Hydroptila</i>	CFF	-	U	-	-
Total taxa, Riffles I and II				19	41	40	50

Table A2  
Macroinvertebrate Species Present in Quantitative Sediment  
Samples Collected in the Pool at the Gravel Bar, 1985-86\*

Phylum	Class	Scientific Name	Trophic Status	1985		1986	
				Jun	Oct	Jun	Oct
Coelenterata		<i>Hydra</i> sp.	P	-	C	U	C
		<i>Cordylophra lacustris</i>		-	-	U	C
Platyhelminthes		<i>Dugesia tigrina</i>	S	-	U	-	C
Nematode worms				-	U	U	A
Bryozoa		Plumatellidae	CFF	-	-	U	-
		<i>Pottsiella erecta</i>		-	-	U	-
Entoprocta		<i>Urnatella gracilis</i>	CFF	A	A	A	A
Annelida	Oligochaeta	<i>Branchiura sowerbyi</i>	CDF	-	C	-	C
		<i>Brattslavia bilongata</i>	CDF	-	-	-	U
		<i>Dero nivea</i>	CDF	-	C	C	A
		<i>D. obtusa</i>	CDF	-	-	-	C
		<i>D. sp.</i>	CDF	-	-	-	C
		<i>Limnodrilus maumeensis</i>	CDF	-	-	U	-
		<i>L. udekemianus</i>	CDF	-	-	U	C
		<i>Nais barbata</i>	CDF	-	-	-	U
		<i>N. behningi</i>	CDF	-	-	-	U
		<i>N. pardalis</i>	CDF	-	C	-	C
		<i>N. pseudobtusa</i>	CDF	-	-	-	U
		<i>N. simplex</i>	CDF	-	-	-	C
		<i>N. variabilis</i>	CDF	-	-	U	-
		<i>Slavina appendiculata</i>	CDF	-	U	-	-
		<i>Specaria josinae</i>	CDF	-	-	U	-
		Tubificidae	CDF	-	C	U	C
		Lumbriculidae	CDF	-	-	U	-
Mollusca	Bivalvia	<i>Corbicula fluminea</i>	CFF	-	C	C	A
		<i>Leptodea fragilis</i>	CFF	U	-	-	-
		<i>Obliquaria reflexa</i>	CFF	-	-	-	U
	Gastropoda	Ancylidae (limpets)	S	-	U	C	A
		Snails	S	-	-	-	U
	Crustacea	<i>Asellus</i> sp.	CDF	-	-	-	U
Arthropoda	Insecta	<i>Ablabesmyia parajanto</i>	P	-	-	-	C
		<i>Chaoborus</i> sp.	P	-	C	-	-
		<i>Cladotanytarsus manicus</i> gr.	CFF	-	C	C	-
		<i>Cryptochironomus fulvus</i> gr.	P	U	C	U	U
		<i>Dirotendipes neomodestus</i>	P	U	U	U	C
		<i>D. nervosus</i> Type I	P	U	-	C	C
		<i>D. nervosus</i> Type II	P	U	-	-	A
		<i>Dirotendipes</i> sp.	S	-	-	-	A
		<i>Glyptotendipes</i> nr. <i>lobiferus</i>	S	C	A	C	A
		<i>Nanocladius distinctus</i>	CDF	U	C	C	C
		<i>N. minimus</i>	CDF	-	-	-	U
		<i>Orthocladius</i> prob. <i>annectens</i>	CDF	-	-	-	C
		<i>Parachironomus abortivus</i>	C, CDF	-	-	-	C

(Continued)

- \* P = predator.  
S = scraper.  
CFF = collector, filter feeder  
CDF = collector, deposit feeder.  
U = uncommon, in 10 percent or less of the samples.  
A = abundant, collected 90 percent or more of the samples.  
C = common, collected more than 10 but less than 90 percent of the samples.

Table A2 (Concluded)

Phylum	Class	Scientific Name	Trophic Status	1985		1986	
				Jun	Oct	Jun	Oct
Arthropoda (Continued)	Insecta	<i>I. frequens</i>	C,CDF	-	-	U	U
		<i>Polypedilum spaldenianum</i> (Schrank)	C,CDF	-	-	C	U
		<i>Pseudochironomus</i> sp.	C,CDF	-	-	U	C
		<i>Rhectanptareus erioqui</i> gr.	CEF	-	-	-	-
		<i>Tanytarsus quinque</i> gr.	CEF	-	-	-	C
		Unknown Chironomidae	CEF	-	C	-	C
	Ephemeroptera	<i>Heptagenia</i> sp.	CEF	-	U	U	C
	Odonata	<i>Argia vires</i>	P	-	-	-	U
	Trichoptera	<i>Chamaetypus</i> sp.	CEF	-	U	-	-
		Hydropsychidae	CEF	-	-	-	U
		<i>Limnephila</i> sp.	CEF	-	C	-	C
		<i>Leptotarsus</i> sp.	-	-	-	U	-
		<i>Leptotarsus</i> sp.	-	-	-	-	C
	Total taxa, pool			9	20	25	39

Table A3  
Comparison of Mean Densities (Numbers/m<sup>2</sup>) for Invertebrates at the  
 Columbus Gravel Bar Habitat Between June 1985 and October 1985

<u>Comparison</u>	<u>Site</u>	<u>t*</u>	<u>df**</u>	<u>Probability†</u>
Total invertebrates (without <i>Corbicula</i> )	RI	11.48	28	a
	RII	6.46	28	a
	Pool	6.31	18	a
<i>Corbicula</i>	RI	3.82	28	a
	RII	3.60	28	b
	Pool	--††	--	--
<i>Glyptodendipes</i> sp.	RI	12.53	28	a
	RII	7.86	28	a
	Pool	3.03	18	b
Naididae	RI	5.06	28	a
	RII	4.61	28	a
	Pool	--	--	--

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\* t = value from Student's t-test.

\*\* df = degrees of freedom.

† a = >0.01 level; b = >0.05 level; c = >0.10 level.

†† Not calculated.

Table A4  
Comparison of Mean Densities (Numbers/m<sup>2</sup>) for Invertebrates at the  
 Columbus Gravel Bar Habitat Between June 1986 and October 1986

<u>Comparison</u>	<u>Site</u>	<u>t*</u>	<u>df**</u>	<u>Probability†</u>
Total invertebrates (without <i>Corbicula</i> )	RI	3.31	8	c
	RII	2.74	8	c
	Pool	2.53	8	c
<i>Corbicula</i>	RI	2.49	8	c
	RII	4.59	8	b
	Pool	7.79	8	a
<i>Glyptodendipes</i> sp.	RI	3.80	8	b
	RII	2.20	8	ns
	Pool	3.57	8	b
Naididae	RI	1.10	8	ns
	RII	2.68	8	c
	Pool	2.65	8	c

\* t = value from Student's t-test.

\*\* df = degrees of freedom.

† a = >0.01 level; b = >0.05 level; c = >0.10 level; ns = not significant.

Table A5  
Comparison of Mean Densities (Numbers/m<sup>2</sup>) for Invertebrates at the  
Columbus Gravel Bar Habitat Between June 1985 and June 1986

<u>Comparison</u>	<u>Site</u>	<u>t*</u>	<u>df**</u>	<u>Probability†</u>
Total invertebrates (without <i>Corbicula</i> )	RI	1.99	18	ns
	RII	0.07	18	ns
	Pool	2.12	8	ns
<i>Corbicula</i>	RI	4.08	18	a
	RII	4.37	18	b
	Pool	4.93	8	b
<i>Glyptodendipes</i> sp.	RI	1.93	18	ns
	RII	4.01	18	a
	Pool	1.95	8	ns
Naididae	RI	0.07	18	ns
	RII	6.49	18	a
	Pool	2.71	8	c

\* t = value from Student's t-test.

\*\* df = degrees of freedom.

† a = >0.01 level; b = >0.05 level; c = >0.10 level; ns = not significant.

Table A6  
Comparison of Mean Densities (Numbers/m<sup>2</sup>) for Invertebrates at the  
Columbus Gravel Bar Habitat Between October 1985 and October 1986

<u>Comparison</u>	<u>Site</u>	<u>t*</u>	<u>df**</u>	<u>Probability†</u>
Total invertebrates (without <i>Corbicula</i> )	RI	0.60	18	ns
	RII	1.44	18	ns
	Pool	1.95	8	ns
<i>Corbicula</i>	RI	1.86	18	a
	RII	2.86	18	b
	Pool	--††	--	--
<i>Glyptodendipes</i> sp.	RI	3.32	18	b
	RII	1.31	18	ns
	Pool	1.11	8	ns
Naididae	RI	5.97	18	a
	RII	4.06	18	a
	Pool	--	--	--

\* t = value from Student's t-test.

\*\* df = degrees of freedom.

† a = >0.01 level; b = >0.05 level; c = >0.10 level; ns = not significant.

†† Not calculated.

Table A7

Comparison of Macroinvertebrates Collected in the Tombigbee River (RM 370, near Columbus, Miss.), October 1974 (Teledyne Brown Engineering 1975\*), the Natural Gravel Bar on the Buttahatchie River in 1981 (Miller, King, and Glover (1983), and the Columbus Gravel Bars in 1985-86

Taxa	Location		
	Plymouth Bluff	Buttahatchie River	Columbus Gravel Bar
<b>Ephemeroptera</b>			
<i>Hexagenia bilineata</i>	X	-	-
<i>Stenonema femoratum</i>	X	-	-
<i>Stenonema tripunctatum</i>	X	-	-
<i>Stenonema</i>	X	X	-
<i>Heptagenia</i>	X	-	-
<i>Tricorythodes</i>	X	X	-
<i>Isonychia</i>	X	X	-
<b>Odonata</b>			
<i>Hetaerina americana</i>	X	-	-
<i>Argia</i>	X	-	X
<i>Ophiogomphus</i>	X	-	-
<i>Gomphus</i>	X	X	-
<i>Boyeria vinosa</i>	X	-	-
<i>Macromia</i>	X	-	-
<i>Neurocordulia</i>	X	-	-
<i>Pantala hymenea</i>	X	-	-
<b>Plecoptera</b>			
<i>Neoperla clymene</i>	X	-	-
<b>Magaloptera</b>			
<b>Coleoptera</b>			
<i>Macronychus glabratus</i>	X	-	-
<i>Ancryonyx variegata</i>	X	-	-
<i>Stenelmis</i>	X	-	-
<i>Helichus lithophilus</i>	X	-	-
<i>Berosus</i>	X	-	-
<i>Dineutus</i>	X	-	-

(Continued)

\* See References at the end of the main text.

Table A7 (Concluded)

Taxa	Location		
	Plymouth Bluff	Buttahatchie River	Columbus Gravel Bar
<b>Trichoptera</b>			
<i>Hydropsyche</i>	X	-	X
<i>Cheumatopsyche</i>	X	X	X
<i>Macronema</i>	X	X	-
<i>Potamyia flava</i>	X	-	-
<i>Neureclipsis</i>	X	-	-
<i>Chimarra socia</i>	X	-	-
<b>Diptera</b>			
<b>Chironomidae</b>	X	X	X
<i>Procladius</i>	X	-	-
<i>Cryptochironomus</i>	X	X	X
<i>Simulium luggeria</i>	X	-	-
<i>Simulium</i>	X	-	-
<b>Decapoda</b>			
<i>Orconectes perfectus</i>	X	-	-
<b>Oligochaeta</b>	X	X	X
<b>Hirudinea</b>	X	-	X
<b>Total taxa</b>	<b>36</b>	<b>18</b>	<b>11</b>

Table A8

Comparison of Invertebrate Density and Frequency of Occurrence at the  
Natural Gravel Bar on the Buttahatchie River (August 1981) and the  
Columbus Gravel Bar on the Tombigbee River (October 1985)\*

Taxa	Density (No./m <sup>2</sup> )		Percent Occurrence	
	Buttahatchie	Tombigbee	Buttahatchie	Tombigbee
Nematoda	28.8	140.6	25.0	80.0
Oligochaeta				
<i>Branchiura sowerbyi</i>	64.7	34.4	33.3	40.0
<i>Dero nivea</i>	24.0	157.8	25.0	80.0
Pelecypoda				
<i>Corbicula fluminea</i>	292.0	361.6	100.0	80.0
Trichoptera				
<i>Cheumatopsyche</i>	79.0	103.3	50.0	60.0
Ephemeroptera				
<i>Caenis</i>	28.7	2.8	41.7	8.3
Diptera				
<i>Clyptotendipes</i>				
nr <i>senilis</i>	104.7	--	58.3	--
nr <i>lobiferus</i>	--	9706.3	--	100.0

\* Only major taxa have been compared.

Table A9

Total and Percent Taxa in Each Functional-Feeding Group for the Columbus  
Gravel Bar (October 1985) and Buttahatchie River (August 1981)

Functional Group	Taxa			
	Columbus Site		Buttahatchie River	
	No.	%	No.	%
Collector	40	75	40	80
gatherer	32	60	27	54
filterer	8	15	13	26
Scraper	4	8	2	4
Shredder	0	0	1	2
Predator	<u>9</u>	<u>17</u>	<u>7</u>	<u>14</u>
Total	53	100	50	100

Table A10

## Fishes Collected in or Adjacent to the Gravel Bar 1985-86

Family	Scientific Name	Common Name	Status*
Lepisosteidae	<i>Lepisosteus oculatus</i>	Spotted gar	U
	<i>Lepisosteus osseus</i>	Longnose gar	U
Amiidae	<i>Amia calva</i>	Bowfin	U
Clupeidae	<i>Dorosoma petenense</i>	Threadfin shad	C
	<i>Doromosa cepedianum</i>	Gizzard shad	C
Cyprinidae	<i>Cyprinus carpio</i>	Common carp	U
	<i>Notemigonus crysoleucas</i>	Golden shiner	C
	<i>Hybopsis storeriana</i>	Silver chub	U
	<i>Notropis venustus</i>	Blacktail shiner	C
	<i>Notropis stilbius</i>	Silverstripe shiner	C
	<i>Notropis atherinoides</i>	Emerald shiner	C
	<i>Notropis emiliae</i>	Pugnose minnow	U
	<i>Hybognathus nuchalis</i>	Silvery minnow	U
	<i>Pimephales vigilax</i>	Bullhead minnow	C
Catostomidae	<i>Cypleptus elongatus</i>	Blue sucker	U
	<i>Ictiobus cyprinellus</i>	Bigmouth buffalo	U
	<i>Ictiobus bubalus</i>	Smallmouth buffalo	C
	<i>Carpionodes carpio</i>	River carpsucker	C
	<i>Moxostoma carinatum</i>	River redhorse	U
	<i>Moxostoma poecilurum</i>	Blacktail redhorse	U
Ictaluridae	<i>Ictalurus punctatus</i>	Channel catfish	U
	<i>Ictalurus furcatus</i>	Blue catfish	U
	<i>Pylodictis olivaris</i>	Flathead catfish	U
Belonidae	<i>Strongylura marina</i>	Needlefish	U
Cyprinodontidae	<i>Fundulus notatus</i>	Blackstripe topminnow	C
	<i>Fundulus olivaceus</i>	Blackspotted topminnow	C
Poeciliidae	<i>Gambusia affinis</i>	Mosquitofish	C
Atherinidae	<i>Labidesthes sicculus</i>	Brook silverside	C
Centrarchidae	<i>Micropterus punctulatus</i>	Spotted bass	U
	<i>Micropterus salmoides</i>	Largemouth bass	C
	<i>Lepomis gulosus</i>	Warmouth	U
	<i>Lepomis macrochirus</i>	Bluegill	C
	<i>Lepomis humilis</i>	Orange spotted sunfish	C
	<i>Lepomis microlophus</i>	Redear sunfish	U
	<i>Lepomis megalotis</i>	Longear sunfish	U
	<i>Lepomis punctatus</i>	Spotted sunfish	U
	<i>Pomoxis annularis</i>	White crappie	C
	<i>Pomoxis nigromaculatus</i>	Black crappie	U

(Continued)

\* C = Common, U = Uncommon.

Table A10 (Concluded)

Family	Scientific Name	Common Name	Status*
Percidae	<i>Ammocrypta asprella</i>	Crystal darter	U
	<i>Percina shumardi</i>	River darter	U
	<i>Percina caprodes</i>	Logperch	U
Sciaenidae	<i>Aplodinotus grunniens</i>	Freshwater drum	C

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